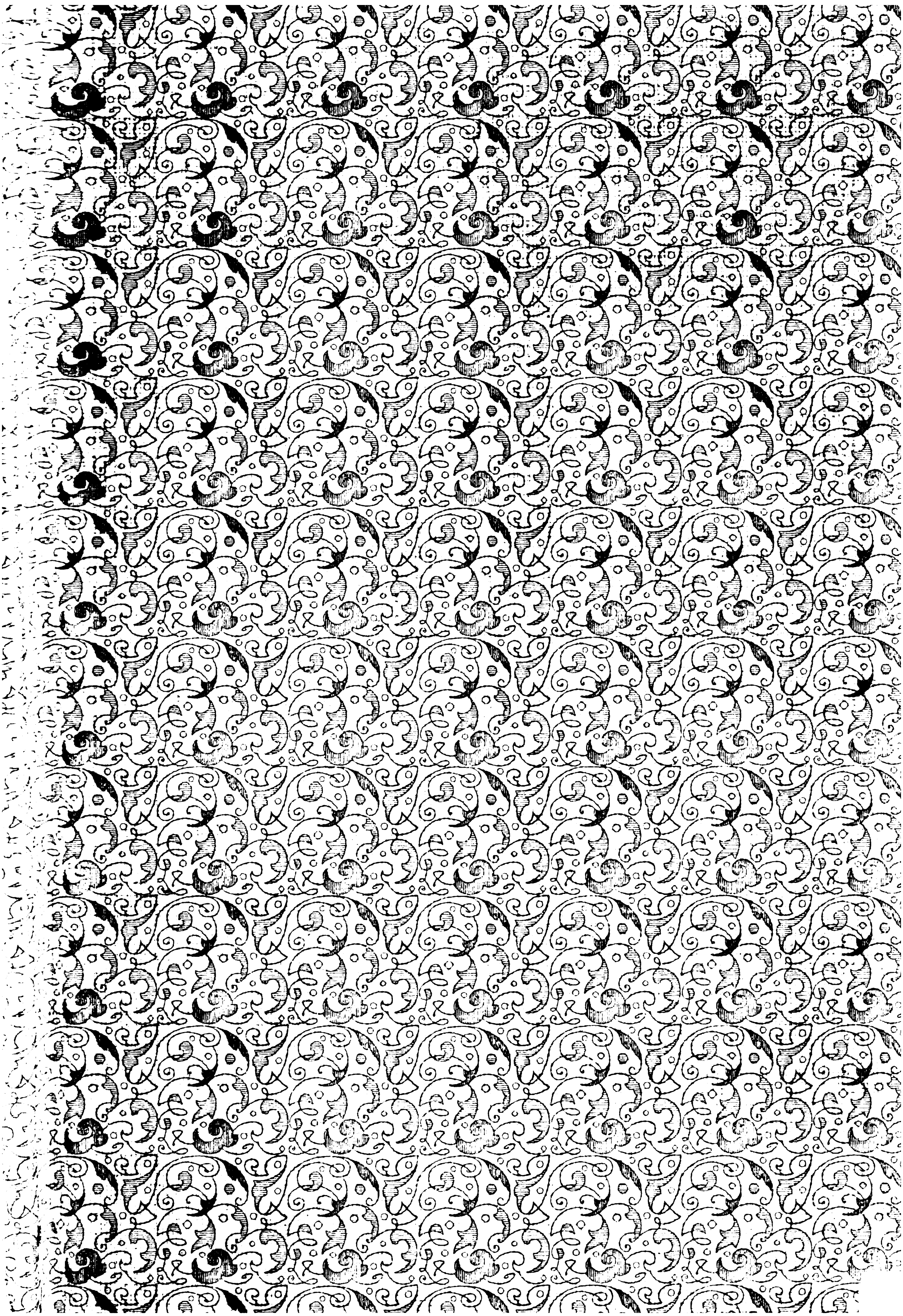

Egypt

SURVEY DEPARTMENT, PUBLIC WORKS MINISTRY

GEOLOGICAL SURVEY REPORT

TOPOGRAPHY AND GEOLOGY

OF THE

EASTERN DESERT OF EGYPT

CENTRAL PORTION

BY

T. BARRON, A.R.C.S., F.G.S. and W.F. HUME, D. Sc. A.R.S.M., F.G.S.

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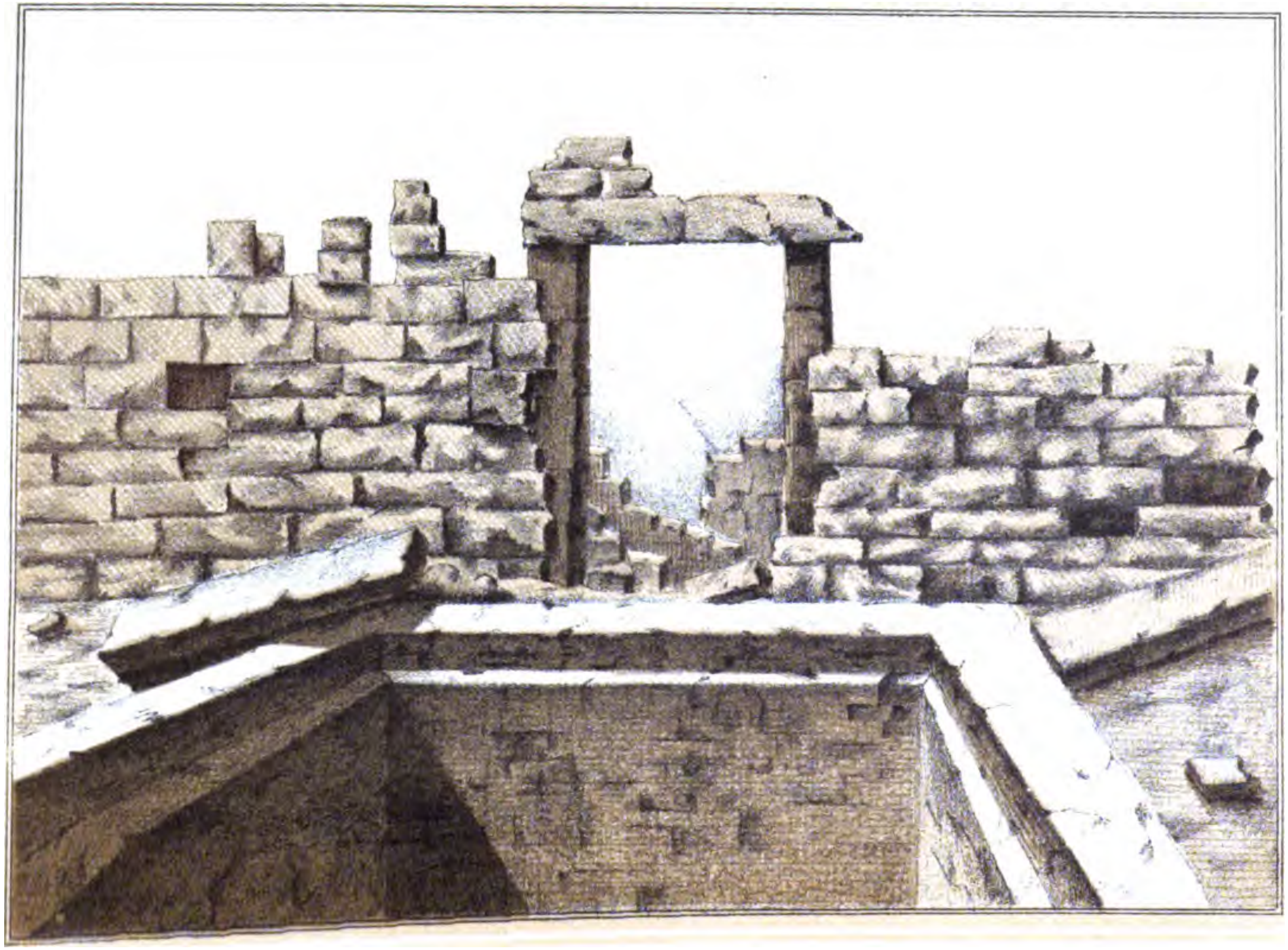
Photogravure by Dr. E. Albert & Co. Munich.

RUINED TEMPLE AT JEBEL DOKHAN.

PLATE X.



Bath in Roman Ruin near Jebel Dokhan.

VIEW ACROSS HEAD OF WADI BELIH WITH SOUTHERN SPUR OF DOKHAN RANGE IN THE BACKGROUND

VIEW ACROSS HEAD OF WADI BELIH WITH SOUTHERN SPUR OF DOKHAN RANGE IN THE BACKGROUND

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Geology.

LIST OF ILLUSTRATIONS.

ERRATA AND CORRIGENDA.

Page.	Line from top.	DESCRIPTION.
25	7	For " *Cerasites*" read " *Cerastes.*"
27	in note	For "anæroid dertermination" read "aneroid determination."
31	in note	For "assended" read "ascended."
31	in note	For "îew" read "few."
33	7	For "the" read "west."
41	34	Before "the north" insert "from."
45	27	Before "be described" delete "to."
52	32	For "Atola" read "Atolla."
53	note	For " *Solamun*" read " *Solanum.*"
74	30	For "ahout" read "about."
85	35	For "Ramses" read "Rameses."
89	40	For "Phospate" read "Phosphate."
90	3	For "Caillard" read Cailliaud."
99	22	For "taghr" read "tagha."
99	33	For " *Zolikoferia*" read " *Zollikoferia.*"
99	last line	For " *Hyocyamus*" read " *Hyoscyamus.*"
100	table	For " *Artemisa*" read " *Artemisia.*"
142	in list	For " *Collumbella*" read " *Columbella.*"
168	margin	For "Selimat" read "Sellimat."
251	34	For "Hammana" read "Hammama."
262	2	Delete "is."
273	24	For "ozokorite" read "ozokerite."
279	8	For "breaking" read "break."
287	34	Before "traveller" insert "the."
288	12	For "similiar" read "similar."

Note.—On pp. 173–174, some difficulty was felt on stratigraphical grounds in accepting Blanckenhorn's view that *Pecten Farafrensis* and *Pecten Mayer-Eymari* were one and the same species. Since this memoir was printed Dr. J. Wanner (" Die Fauna der obersten weissen Kreide der libyschen Wüste, Palaeontographica," 1902, vol. XXX, p. 114 and Plate XVII, Fig. 1–3.) has described and figured Prof. Zittel's type of *P. Farafrensis*, and a comparison with *P. Mayer-Eymari* certainly appears to justify Dr. Blanckenhorn's contention. We have reason to believe that Mr. Bullen-Newton shares these views, the acceptance of which unfortunately complicates what at first sight appears a simple problem.

Memoir printed on 17 March, 1902.

INTRODUCTION.

This memoir deals with the country explored by the Geological Survey during the season 1897-98, the region studied extending between lat. 26° and 28° N. and lying between long. 33° E. and the Red Sea. Two parties were engaged for a little over six months in traversing and mapping the area, the characters of which are discussed in the following pages, Qena being in each case the starting point. In 1897 Barron and G. D. Cooke examined the Qena-Qosseir road via El Geita and Wadi Hammamat and the coast-plain of the Red Sea from Qosseir to Wadi Safaja, returning from this point via Wadi Markh to Qena, while Hume and F. W. Green followed a northern route from Qena to Qosseir, from thence going direct north to El Shayeb and Mons Claudianus, and returning to Qena by a road leading round the southern edge of Abu Had. A joint expedition was also made by Barron and Hume to Jebel 'Aradia, Green mapping the route. Introduction.

In 1898, the two parties examined Wadi Qena as far as the northern end of Abu Had, where they parted. The longest traverse of all was the last, Barron, T. Dillon, and S. T. Hardwick going east along Wadi Fatiri and Wadi Um Tagher to the coast plain, from whence they followed the Red Sea coast until they went inland to meet the other party at Jebel Dokhan. From here they went eastward to Bir Mellaha and Jebel 'Esh towards Ras Jemsa and Jebel Zeit, at which point the other party met them after their traverse in the igneoushills. From Jebel Zeit the parties went together as far as Jebel Mongul, where they again parted, Barron's group working up the coast and round Gharib, the work finishing at Gharib light-house. At the same time Hume and Cooke went from Qena to Bir Um Disi, examined the interior valleys of Gattar and the western slopes of Dokhan and Abu Harba, and travelling to Dokhan, where Barron's party was met, followed the hills to the latitude

of Jebel Kufra, thence crossing by Bir Mellaha to Jebel Zeit. At Jebel Dara the parties separated, the last named making a traverse in the hills to visit the Roman Hæmatite mines of Wadi Dib, and the slopes of Guereb and Gharib.

As regards the map on the 1:500,000 scale the district between Qena and Qosseir as far as Wadi Fatiri is the work of Green, while Dillon has contributed the Fatiri road, the Wadi Qena, and all the hill districts bordering the Red Sea north of Safaja. The map of a portion of the southern road from Qena to Qosseir and Qosseir to Safaja has been taken from sheets by Cooke.

In addition to the materials due to the survey itself, advantage has been taken of the publication of Dr. Schweinfurth's new maps to fill in several gaps in the northern portion of the district, while Green lent a series of sheets prepared by him, which have enabled the addition of the south-western districts between Qift, Qena, and El Geita. The cliffs of the Eocene plateau near Qena (Jebel El Shadin) are from the sheets of Beadnell and Gorringe. Plate III is mainly a reduction of the original map made by Green, and Plates IV to VII, are taken direct from Dillon's field-sheets.

In addition to the map work done by the Survey, Cooke prepared a set of panoramic sketches of the Red Sea Hills, which were coloured geologically under Hume's direction.*

Equipment. Each party consisted of a Geologist and a Surveyor, and was supplied with the following equipment:—

Three tents—one of which was for the servants.
Four galvanised iron water-tanks holding 40 litres each.
One measuring-wheel.
One planetable.
One trough compass.
One circular compass.
One 10 metre, and one 20 metre steel tape.
Geological hammers, collecting bags.
One theodolite, 6″ or 8″.
One hack watch.
An aneroid and hypsometer.

*The topographical portion of this volume is based on the field notes collected by Barron and Hume, and topographical field-reports prepared by Hume, Green and Dillon. The Plates were drawn by Letchford from photographs taken by Green and Barron.

The relative responsibility for the various sections, or parts of sections, is indicated by the initials T.B. or W.F.H. Where, as in the majority of instances, each writer has contributed materials, the initials of the one are put first who, in the opinion of the joint authors has probably contributed most.

Other abbreviations adopted throughout this work are J.=Jebel (mountain), and W.=Wadi (valley)

Each party had fifteen camels, these consisting of thirteen baggage camels and two riding camels, the latter being for the use of the surveyors. To look after the animals there were nine drivers; and two men were hired in addition, one to carry the plane-table up hills, and the other to push the measuring wheel.

The camels and men were hired from the sub-sheikh of the Maaza, Suleiman Farag, with whom a contract was made binding him to supply the parties with whatever number of camels was required, at 120 millièmes per day. Two drivers were also to be supplied for every three camels, but their pay was included in the camel hire. It was also agreed that the camels were to be in good condition, having saddles, ropes, and headstalls perfect, and if any animal shewed signs of sore back or sickness it was to be replaced at once by another. The drivers were also to assist in pitching camp, in packing up, and in finding water and fuel; and two of them were required to be well acquainted with the country so as to act as guides. Each man was to supply himself with food, and "qirab" (waterskins) to carry his own water. The load for each camel was fixed at 3 qantars = 300 lbs., exclusive of camel food, etc.

Methods of work.

As was stated previously, the work was all done by traverse. This was accomplished by using the measuring-wheel to give a base and then fixing points on either side by intersection, such points being afterwards used as checks as the work proceeded. On account of the scarcity of water in the desert it was necessary on an average to make a march each day of about 7 or 8 kilometres; it thus involved rather hurried work.

To act as a check on the work, observations for latitude were taken each evening, and observations were also taken every three or four nights, to find the local mean time. At certain intervals, observations on north and south stars were made to determine the latitude with greater accuracy.

Heights of hills climbed were determined by aneroid, by keeping a chain of observations from a point of known height above sea-level, or if possible from the sea itself; if any closing error was found it was distributed over the series. In the case of the most important peaks, hypsometer observations were also made in conjunction with those of the aneroid. Where the conditions were favourable, observations were made by the theodolite to determine the heights of important hills.

A source of trouble was the measuring-wheel going out of order, and often breaking down, when it was necessary to adopt a time scale,

the rate of march of a camel being taken at 4 kilometres per hour. This had to be adopted towards the end of the long traverse.

One of the greatest obstacles to correct surveying in this district is the presence of great masses of magnetic rock in the hills.

Another source of error is found in the mirage, which is often met with in crossing large plains, causing a distortion of the points and often making peaks which are ordinarily invisible appear above the horizon.

T. B.

PART I.

TOPOGRAPHY OF THE RED SEA HILLS.

The topography of the district examined falls naturally into several broad divisions, very well marked on the western side towards the Nile, but obscured by complex tectonic changes towards the Red Sea.

SECTION I.—LIMESTONE PLATEAU COUNTRY.

The cliff immediately north of Qena* (Arabic قنا) marks the end of the more regular limestone plateau, which is bounded on the west by the Nile, and on the east by the broad valley of Wadi Qena. In going up this wadi, there is a prominent cliff, over 300 metres high on the western side, this being the edge of a table-land, which sends out long tongues, such as those of Jebel El Shadin and Arras, or is penetrated by deep bays and valleys, viz., El Shadin and Gurdi. In addition to the main plateau, there are two groups of hills, lying to the east and south, possessing a similar flat-topped character and geologically identical, but separated from it by a wide area of lower ground. Limestone Plateau.

One of these, Jebel Abu Had, has now been correctly mapped for the first time, and proves to be a long triangular wedge, with the apex pointing southward, while at the northern end, Wadi Abu Had forms a deep V-shaped bay, bounded on both sides by high ridges rising 180 to 210 metres above the plain. The western spur is simply a long narrow ridge, bordered by abrupt cliffs of the flinty Eocene series, while the eastern hills are, on the contrary, wider and flatter, having still preserved some traces of the plateau from which they were derived, but towards the valley they have been worn into sharp pyramids or cones. Jebel Abu Had.

To the south-west the plateau structure predominates, the valleys being all cañon-like.

*The Arabic ق is throughout this disirict pronounced as a G or K.

Jebel Serrai and El Jir.

A second range, Jebel Serrai and El Jir, lies nearly due east of Qena, and is separated both from J. Abu Had and the main plateau by Wadi Qena and low hill country. From below, this range appears to be the edge of a continuous plateau, but an ascent of Jebel Serrai showed that this was not the case, the summit being but part of a long thin ridge, sometimes only 3 metres broad, behind which the table-land had been cut down by deep ravines similar to those in Abu Had, though erosion has gone much further in Serrai.

The northern part of Jebel Serrai presents two fine examples of the wearing away of parts of the slopes into great amphitheatres (of which Wadi Abu Had is possibly an extreme case) the maximum concavity being north-west.

Wadi Qena.

Topographically the country between these three plateaux is not very striking, Wadi Qena, near Qena, forming a broad pebble-covered plain, bounded on both sides by low gravel ridges.

Wadi El Shadin.

The large wadi of El Shadin enters it from the north, and, viewed from Jebel Arras, is seen to be made up of several branches which have cut steep-sided courses in the low secondary plateau. It is bounded on the west by the precipitous projecting ledge of Jebel el Shadin, far back to the north by the main cliffs of the Eocene plateau, and to the west by the projecting hill of Jebel Arras.

Wadi Qena is itself at first essentially uninteresting, being only broken by shallow watercourses, where vegetation is of a scanty description, the most noticeable feature being the trailing stems of the "handal," or colocynth (*Citrullus Colocynthis*, Schräd.), bearing the well-known yellow globular apple containing an intensely bitter juice, and bushes of the prickly crucifer, "bsilla" (*Zilla myagroides*, Forsk.) which is abundant both here and in El Shadin. This plant is a favourite camel food, these animals eating the spinose branches with every sign of relish.

At the foot of Jebel Arras a few "Sellim" bushes (*Acacia Ehrenbergiana*, Hayne) were noted, but these were the only shrubs up to that point.

Jebel Arras.

The foot-hills of Jebel Arras are the first marked features, these ending in abrupt cliff faces of pebble conglomerate 15 metres high. They pass into a second range of higher foot-hills, and finally behind them rise the abrupt sides of Jebel Arras, having the white or yellowish colour characteristic of the whole Egyptian limestone region.

Bir Arras.

At the foot of the conglomerate cliffs forming the lower slopes of Jebel Arras is the small well of Bir Arras, a hole dug in the ground, which at the time it was visited was practically empty, except for a small

quantity of water about $1\frac{1}{2}$ metres below the surface sand and gravel. In the immediate neighbourhood of the Bir camel food is plentiful, but elsewhere it is scanty.

There is close to this spot a great widening of the wadi as it is here formed by the junction of three branches, one, the main valley, Wadi Qena, coming from the north, while the two others, Wadis Gareya and Um Sellimat, join it from the east. The main wadi as far as explored will be considered first.

Wadi Qena (continued). After passing Bir Arras, hummocks of earth are noticeable, these being due to dead tamarisk bushes having been covered up with blown sand or earth with the leaves and other vegetable remains brought down by the rains. These heaps supply a small quantity of rotten wood which is collected and sold in Qena. Wadi Qena here turns north with a slight westward trend, and from being a wide plain, becomes somewhat narrowed between the main Eocene plateau and the outlying range of Abu Had, while to the east, the pebble-covered expanse is succeeded by low broken hills of white sandy limestone, which still further eastward first form low ridges and finally constitute a secondary plateau. Between Jebel Arras and the mouth of Wadi Gurdi several isolated knolls of pebble gravel rise from the centre of the valley, while a large number of feathery tamarisk bushes give variety to the otherwise sterile waste. At the same time, the fine perpendicular cliffs of J. Arras and J. Abu Had, rising 300 metres above the wadi on both sides, form striking features in the landscape. The valley has been surveyed as far as the northern end of Abu Had, where a caravan road to Bir Um Disi and J. Dokhan, J. Zeit, etc., bends sharply eastward, and passes from the plain into a series of low hills cut by watercourses and formed of a sandy limestone.

Wadi Gurdi. On the western side of Wadi Qena, the cliffs of Arras bend north-west, forming the southern boundary of Wadi Gurdi, which opens into the main valley at this point.

Wadi Abu Had. On rounding the western spur, the huge bay of Wadi Abu Had is entered, and has received special attention as the camp had to remain here for several days while the camels went back to Qena for water. The valley, as already stated, runs far into the range, and is connected by a road (bad for camels) with the broad wadi east of Jebel Abu Had, the Nagateir plain.

The region is very desolate and but seldom visited by the Arabs there being a total absence of both water and good camel food. In fact the vegetation consists almost entirely of "bowal" (*Zygophyllum coccineum* probably predominating), with its pulpy cylindrical leaves

and salty sap, "kusha'id", a very spinose type, with a five-lobed fruit, and in addition an abundance of "had" looking like dead wood in February, and forming an excellent fuel. These latter are both species of Fagonia, while all three are members of the Zygophyllaceæ. The name Abu Had is derived from the occurrence of the "had" above-mentioned.

The plants common in Wadi Qena, espescially "bsilla" and "markh," are almost entirely absent, while the only representatives of animal life noted were a hare and a quail.

Musical sand. The hill which forms the last summit of the western spur had long sand slopes, and stones rolled down these gave rise to a marked musical note.

To the south-west the plateau-structure predominates, the valleys being all cañon-like. On entering the main valley their combined drainage takes a north-westerly course, then after bending west round the foothills of sandy limestone, joins the southward trending water-courses of Wadi Qena. This is bounded on the east by the sandy limestones, on the gravel plateau of whose projecting western end stands the Roman station of El Heita, commanding a view of both the main wadi and the eastern road followed by the Survey.

Roman Station of El Heita.

Wadi Abu Had itself consists of low gravel plateaux intersected by wide secondary valleys. The survey was carried out by running a set of stations up the valley and subsequently ascending some of the more prominent heights east and south of it. On the north most of the points have been repeatedly checked. The valley is broken by two marked points, a yellow hill and a small mound, the latter being of especial geological interest as being an igneous neck.

From here a rapid traverse had to be made to Bir Um Disi. The track meandered across valleys and over low gravel hills, passing between the main Abu Had range, and a prominent outlier Jebel Nagateir (spelt Nagaler on Zittel's map).

Beyond these hills (to the east) lies the broad plain of Wadi Fatiri, the drainage in which runs north-west then bends west and finally turns south into Wadi Qena. This curious northward trend was also remarked by Green in the Nagateir portion of the valley further to the south.

Thus at both the north-east and north-west extremities of Abu Had there are groups of foot-hills to the north of which the northward-flowing drainages of Abu Had and Fatiri completely bend round to unite with the southward-flowing Qena system. Wadi Qena appears to be bounded on the west for the remainder of its course by the cliffs of the limestone plateau, which, broken in places by the openings of large wadis, finally bend round east to form the Galala range.

Returning to Bir Arras, it has been stated that a large valley, Wadi Gareya, opens into Wadi Qena from the east, having broken through the lower plateau (on its western margin now consisting of detached hills), which otherwise forms an almost continuous barrier extending from Serrai to Abu Had. Wadi Gareya.

Near the eastern edge of the barrier it is joined by a large wadi draining the southern edge of J. Abu Had, and between them these two openings give passage to all the water from Wadi Markh, Wadi Hammama, and Wadi Jidami, connecting the drainage systems of the latter with the main drainage system of Wadi Qena.

The wadi itself is at first wide, and cuts through a low plateau of gravel capping the limestone which slopes upward toward the east, so that at its eastern end the hills on both sides are over 70 metres high. The road itself is a well-marked series of tracks, easy for camels, even if heavily loaded. The drainage line showed evidence of a recent and copious flow of water, large patches of dry mud being left, cracked into cup-shaped pieces by the sun, while camel-food (mainly "bsilla") and fuel were plentiful in patches along it.

In this wadi are the ruins of a "deir"* and another building 40 metres to the west of it, connected to the main structure by what appears to have been a cement-lined water-channel nearly 3 metres wide, all except 20 metres of its length being buried by the sand and gravel of the wadi floor. Ruins in Wadi Gareya.

The main building itself contains a square cement-lined tank and what looks like a well, a D-shaped excavation lined with stones, but from Beduin reports all the water was brought from the Nile, and stored in the tank, the same authorities stating that the place was destroyed, at the Mohammedan invasion. That this is probably an old monastery is shewn by the traces of cells, and especially by the numerous arches which indicate the former presence of cloisters.

Finally, Wadi Gareya leads without any pass direct into a wide plain, called by the guides Wadi Markh or Wadi Hammama, either name being used indifferently.

There is no absolute break between W. Gareya and J. Serrai, but the barrier, here consisting of limestone and marl hills, is traversed by two passes (practicable for baggage camels), connecting westward-sloping gullies with two broader valleys, which unite to form the broad and shallow Wadi Um Sellimat, running parallel to Wadi Gareya, and separated from it by a low plateau of conglomerate cut into cliffs on the north-east side of the wadi. Wadi Um Sellimat.

* Term applies to Coptic monasteries and often to any ruined building.

On the southern side the valley is joined by two large tributaries, known as Wadi Um Haddat el Bahri and Um Haddat el Qibli, draining the eastern slopes of the Serrai range.

Fuel and fodder are scanty in Wadi Um Sellimat, but somewhat more abundant close to the foot of the Serrai range.

Jebel Serrai and El Jir.

Jebel Serrai was ascended from the head of Um Haddat el Bahri. The main range is separated from the portion known as El Jir (which, having been weathered into a white pointed hill forms a conspicuous object as seen from Qena) by a col much lower than than the top of the plateau, which is covered with flint weathered to a deep brown colour.

Stone Circles at foot or Serrai.

Up a small khor running round the back of a spur which forms the north end of Serrai proper, are remains of rude circular stone huts and quantities of broken pottery of apparently ancient date, judging from fragments seen.

Summary.

The limestone plateau district extending from Qena to near Cairo, a distance of four degrees of latitude, is characterised by its flat summits, and though deeply cut into by steep-sided valleys, nevertheless forms a single geographical unit. Speaking generally, wherever it faces the valleys, viz., the Nile Valley on the west, Wadi Qena on the east, or in the Galala hills above the Red Sea and Wadi 'Araba, it is characterised by the steepness of its escarpments, which normally rise over 300 metres above the depressions. In the district under discussion, the limestone plateau has been disturbed by faulting, with the result that two valleys, Wadi Qena and Wadi Gareya, have cut right through the limestone barrier to the Nile, and two isolated limestone ranges have been produced, viz., Jebel Abu Had and Jebel Serrai, while further south the table-land disappears altogether, being replaced by steep and isolated outliers. The edges of the hills are bounded by secondary foot-hills of gravel and sandy limestone, which to the east run together to form a low plateau between Jebels Abu Had and Serrai, only cut through by W. Gareya and its northern tributary. South of W. Gareya this plateau is much cut up by the drainage system of W. Um Sellimat.

W. F. H.

Section II.—CRETACEOUS LIMESTONE PLATEAU.

In the south-western corner of the district is a small limestone plateau running north-west and south-east and owing its origin to hard limestone beds of Cretaceous age, which have not been previously

recorded. It extends from the level of Jebel Serrai† to the southern end of Abu Had, though cut through by Wadi Gareya, and much broken up north of that valley. Where not disturbed, it rises 50 metres above the plain, and is being somewhat rapidly cut back, as the upper beds being harder than the lower, overhanging ledges are produced.

Owing to its broken character where traversed by Gareya, this plateau was not noted on the outward journey to J. 'Aradia, but on the return to Qena it was examined, and proved to be of Cretaceous age, also containing phosphate beds similar to those found by Barron further south in the previous year.* The valleys running through it to the plain from the local watershed are now gullies, (the roads being simply steep paths covered with loose pebbles derived from the gravel capping the higher range of cliffs) leading to the large plateau, which as before stated, slopes gently down to the Wadi Qena.

Track from Um Sellimat to Hammama.

When traversing from Qena to Qosseir, the party taking the northern road, in returning from Jebel Serrai, went up Wadi Um Sellimat to a point about 2 kilometres distant from the main pass leading to Wadi Hammama, whence a single track running to the south of the main road was followed. This path enters Wadi Hammama further to the east than is the case with the main road, as the direction of this wadi is oblique to that of the road. The descent is less steep than that by the main track, but the whole way from the fork is far more stony, especially on the steeper eastern side of the hills, and consequently the northern route is the one usually adopted for laden camels.

At the southern end of Abu Had the Cretaceous plateau bends sharply eastward, and for some distance forms an absolutely precipitous wall facing south, and 50 metres high. Owing to its northern dip of 4°, this plateau soon disappears into the plain, while to the east it is broken up by faults. This portion of the country has not been very fully examined, but there is a distinct watershed at this point, the cause of which has not been determined.

The Cretaceous plateau does not reappear after its disappearance into the plain of Abu Had. When the plateau at the foot of Abu Had is viewed from a distance, small yellow hills are seen rising from it which in certain lights have a peculiarly unreal, or ghost-like appearance. These are the remains of the soft beds at the base of the Eocene series, which are still left, capping the hard Cretaceous limestone. W.F.H.

* *Survey Report:* On the Phosphate Deposits of Egypt. Cairo, 1900.

†See Plate I.

SECTION III.—THE CENTRAL PLAINS.

One of the most noticeable of the topographical features is the wide depression which extends from the north of Wadi Qena to a little north of the Qena-Qosseir road, *i.e.* over two degrees of latitude. This is directly traceable, as far as examined by the Survey, to the geological structure of the country, being everywhere due to the wearing away of the soft marly and sandy beds which form the upper members of the Nubian Sandstone series. It is true that north of the road crossing the Nagateir plain, these Nubian beds no longer appear in the plain itself, but they have been noted under the outlier of Jebel Nagateir at the most northern point examined, while further south they become more and more marked.

These plains have been crossed at seven different points, the principal features connected with them being as follows, beginning from the north:—

Nagateir-Fatiri Plain.

1. *The Nagateir-Fatiri Plain.*—Between J. Abu Had and the Red Sea Hills extends a broad level expanse 15 kilometres wide, broken only by low mounds of gravel or small knolls of a black igneous rock, while further east towards the Fatiri range the remains of a gravel plateau were seen extending to the north, though no longer conspicuous at the point where the road crosses from Abu Had to Um Disi. The drainage of this region presents the peculiar feature that, in order to find its way to the Nile Valley, it has first to flow northward from the extreme southern end of Wadi Abu Had round the northern edge of that range and then is deflected southwards down Wadi Qena, thus running in a horse-shoe-shaped form.

Though in general the plain is covered with gravel, vegetation is in places very abundant in the shallow watercourses, especially "bowal," *(Zygophyllum coccineum)* and the aromatic plant "shia" *(Artemisia judiaca).*

Contrast between east and west boundaries of plain.

The hills which border the plain to west and east respectively stand in sharp contrast to one another, for on the west the flat plateau of Abu Had (continued to the north as isolated outliers), rises as a steep escarpment in general over 200 metres high, and terminates to the south in a bold and conspicuous headland, and to the north in a summit of marked conical form.

On the east, the main hill mass viewed from the plain presents a very fine appearance, there being first low foot-hills which merge gradually into a low dark-coloured range followed by higher crests of a rich

purple or pink hue, the whole backed by the rugged peaks of the central massif, which stand out majestically against the sky-line, the grand summit of El Shayeb ("the old man") rising behind and dominating the whole. Well to the north is seen the dark hill mass of Dokhan, while nearer are the rounded red granite hills of Um Disi and Abu el Hassan, the precipitous walls of Atilmi and Um 'Anab with its nipple-shaped summits, while far to the south appears the familiar form of Jidami* and the long crest of 'Aradia.

With regard to nomenclature, it seems advisable to adopt the name of Nagateir for the whole of the plain, although many of the guides call its northern half Fatiri. The naming depends on the drainage, the wadis being in general referred to by the natives, while the mountains are regarded as subsidiary. For instance, Jebels Um Disi, Gattar, Belih, and Kohela, would be in other countries regarded as one range, but those hills whose water supply drains into Wadi Um Disi are known as Jebel Um Disi, those draining into Wadi Gattar as Jebel Gattar, and so on.

2. *Markh-Hammama Plain.*—Immediately south of the water-parting due in part to the Cretaceous cliff, the country has not been closely examined, but the Cretaceous plateau seems to form part of the northern edge of a basin, which receives the drainage of Wadi Markh on the north and Wadi Hammama on the south, the whole discharging through Wadi Gareya.

Already from the Nagateir road brown-red hillocks of Nubian Sandstone could be seen (though their outlines were obscured by mirage); and in the next mapped traverse to the south, that of Gareya-Jidami, the plain was no longer bounded by foot-hills of granite, but by a sandstone plateau. **Markh Plain.**

On leaving W. Gareya a broad plain is crossed dotted over with small conical yellow-green knolls, which gradually become higher to the east, and finally, capped by a hard ferruginous bed, form a continuous plateau.

3. *Gareya-Hammama.*—The sandstone plateau appears to have been bent back to some extent, as the Hammama plain is wider, but more valley-like. In its characters it agrees with the Markh plain, but after the marly region is passed over, narrows rapidly into a ravine.

Apparently to the south of the Hammama plain the country continues more or less flat as far as the break north of the Qena-Qosseir main road.

* See Photogravure of Jebel Jidami, p. 41.

NOTE.—For the earlier part of the journey to Um Disi, the guide was Rean Abid, of Qosseir, the wheelman who had been with previous expeditions, and had proved very trustworthy in the information he gave. Most of the plants were named by him.

While in origin, these valleys are geographically a single unit, they may be divided into three groups, viz. (*a*) Wadi Qena, draining southward; (*b*) the Nagateir plain, draining northward into Wadi Qena, and (*c*) Markh-Hammama basin, draining through Wadi Gareya into Wadi Qena.

Qena only outlet for northern Red Sea Hill Drainage.

Partly as a result of their existence, and probably due also to faulting of a complex kind, almost the whole of the western drainage of the Red Sea Hills, between lat. 26° and 28° N. enters the Nile Valley at Qena. W.F.H. and T.B.

Section IV.—NUBIAN SANDSTONE PLATEAU.

As has been already stated, in the south-western part of the district the more massive Nubian Sandstone, which is absent between the limestone and granite north of the Nagateir water-parting, forms to the south of that line a marked plateau between the Jarra-Jidami ranges and the Markh-Hammama basin, towards the latter breaking into low tabular and conical greenish-yellow hillocks, while towards the granite it also breaks up into conical hills 100 metres or more high, resting on the igneous floor.

Three well-marked valleys run through this region, two characterised by their steep-sided walls, these being from north to south:—

1. *Wadi Markh.*—On entering the sandstone area this wadi practically becomes a plain, there being no proper sides, and it is crowded with "shia," "bsilla," and "gurdi" (*Ochradenus baccatus*). As it was followed westward, its bed became deeper and low hills appeared forming almost vertical sides. The whole country was markedly different from that through which the Qena-Qosseir road passed, the rock here never assuming the plateau-like character, but rather tending to break up into low ridges and isolated hills.

Wadi Jidami.

2. *Wadi Jidami.*—After leaving the Markh plain the road runs up Wadi Jidami through a fine sandstone ravine on both sides of which are a number of rude drawings of animals, boats and men, as well as inscriptions (Hieroglyphic, Greek, and tribal marks) many of which were copied, though in most cases more time would be required for their correct transcription than was available. In the valley, camel food and fuel was scarce, while water was reported to be in small quantities in the adjoining granite region, rain-water having collected in pools. Finally, Wadi Jidami opens out into a plain of triangular shape, which runs up to the foot of Jebel Jidami. The country west of the plain consists of a low Nubian Sandstone plateau cut up into knolls by

numerous water-courses. At the point where Wadi Jidami leaves the plain of Jidami, igneous rocks make their appearance, capped by small cones of yellow sandstone, but further to the east only the former are visible.

3. *Wadi Hammama.*—This type of country was again re-traversed when returning through Wadi Hammama, which, at the end of Wadi Sellimat, enters a plateau of sandstone resting on igneous rocks, the latter having a slope of about 60°, and in the lower part of the wadi forming steep-sided walls, making it difficult to combine rapid traverse and accurate measurement, since at each turn only a short portion of the route could be observed. **Wadi Hammama.**

In this valley are ruins of buildings apparently connected with the crushing of hæmatite (brought from Abu Jerida), a large number of rubbing stones and fragments of granite being scattered about among the foundations of stone walls. On the top of a low knoll are the foundations of what was possibly a small shrine, a piece of pottery with lotus ornament in dark brown being found in it. In the valley are numerous hieroglyphic inscriptions, none of other kinds being observed east of the ruins. Copies of one or two of the best were made, the greater number being almost defaced, and really requiring squeezes, as copies would be untrustworthy. The discovery of blocks of hæmatite of good quality in this "deir" led to enquiries, the chief guide, Hamed Assawalla, stating that rocks of similar nature occurred to the south, and in consequence, the arrangements for the traverse to Qosseir were so made as to include an examination of this point. (See p. 51). **Ruins of buildings in Hammama.**

In many places in the wadi along the route followed, the steep yellow sandstone cliffs on both sides are covered with inscriptions; at one point these included hieroglyphs, Greek, and Cufic characters, some of which were copied. One of the hieroglyphic inscriptions contains a cartouche very much defaced by weathering; of this Green took a squeeze, and subsequent examination showed it to be of a King of the 5th Dynasty, viz., Sa-u-ra.

The road continues to run for some distance through the sandstone gorge, whose walls are from 50 to 100 metres high, but finally, more open country is reached, and to the south of Hammama the sandstone plateau seems a great deal more broken up.

Resumé of Results West of Red Sea Hills.

It will thus be seen that the topographical conditions are more complicated at the south-west corner of the district, owing partly to

greater geological complexity, and partly to an increase in the faulting of the area. In the south the sandstone plateau rests upon the igneous hills in such a way as to suggest that it once lay upon their summits, but subsequent disturbance has tilted the rocks, so that now they dip northward or westward. As a result there follow in succession from the igneous hills in ascending order; (1) the hard sandstone plateau; (2) the plains, produced by the wearing away of soft sands and marls of the Upper Nubian Sandstone; (3) the Cretaceous plateau due to the rapid wearing away of soft marls and limestones capping beds of hard Cretaceous limestone; (4) the Eocene plateau, forming steep cliffs, usually 200-300 metres high, and shown in all cases examined to be due to faults; (5) in addition, faults have produced outliers from the main Eocene mass, which in turn are surrounded by (6) lower much broken plateaux of gravels and sandy limestone.

To the north-west the conditions appear to be greatly simplified, only a broad valley, or plain, lying between the Eocene escarpment and the igneous hills.—W.F.H. and T.B.

Section V.—THE RED SEA HILLS.

The present map would, if complete, embrace the greater portion of the Red Sea Hills, north of the Qena-Qosseir road, with the exception of the mass of J. Gharib, and the isolated outliers of Hawashia and Tenasseb. Viewed from the Red Sea, a mountain wall is seen to extend from J. Gharib to J. el Shayeb, near lat. 27° N. the summits rising on an average from 1000 to 1500 metres above sea-level, while in the massif of Gattar-El Shayeb 2000 metres are exceeded. North of lat. 27° N. the highest line of summits is on the extreme eastern side of the igneous range, a few high spurs also running transversely, while the numerous lower transverse ridges also all show a certain rough parallelism. To the south of lat. 27° N. the country consists rather of an intricate mass of small hills having no apparent arrangement, out of which rise abruptly granitic ranges or isolated hills, near Qosseir intermixed with tilted and faulted masses of sandstone and limestone which give infinite variety and complexity of scenery, and present a topographical puzzle only to be unravelled by reference to important and far reaching tectonic changes.

1. *Red Sea Hills North of lat. 27° N.*—The northern Red Sea Hills will be first considered, and in treating this part it will be more convenient to examine them from south to north, that is, following the direction of the traverses made across the country. After passing

round the northern edge of Abu Had and crossing the plain of Nagateir, the actual igneous hills, here some 60 metres high, are entered by a comparatively narrow opening through which, nevertheless, passes the drainage of four or five great valleys, meeting close to this point. The principal ones are Wadi el Atrash, draining all the country from J. Abu Harba, Jebel Dokhan, and the hills of Hamra and El Atrash on the west; Wadi Gattar coming from southern Dokhan and Jebel Gattar; and Wadi Um Disi, receiving its water-supply from J. Um Disi and all the high ranges between Um Disi and the Atilmi group. These wadis and their tributaries form one drainage unit, opening by a single mouth into the plain of Nagateir, and through it becoming connected with Wadi Qena.

The road up Wadi Um Disi runs between granite hills, rising from 30 to 60 metres above the valley and running in a direction slightly north of east to north-east. After 5 kilometres the hills change, the granite being succeeded by dark hills, the first one ascended being magnetic. In the valley is a ruined Roman "Deir," connected by a road with a similar one in Wadi el Atrash; in it nothing of interest was obtained, though fragments of pottery and blue glass were present. On the opposite side of the valley is a horse-shoe-shaped artificial ridge, with a depression in the centre, whose exact purpose it is difficult to determine. **Wadi Um Disi.**

While on the north doleritic beds give rise to low hills with rounded or subconical summits, on the south is a high dark chain, with steeply sloping or precipitous sides; these rose 350 metres above the valley at the point ascended, some of the peaks being still higher.

Further up the valley, the wadi passes between low granite hills, penetrated by many green and red veins, while on the right rise high smooth-sided granite hills with rounded summits, belonging to the Abu el Hassan group. Mountain after mountain opens out to the north-east, conspicuous amongst which are the peaks of Atilmi, with a pass between them, the conical dark summit of Kohela and a number of nameless peaks from 1500 to 2000 metres high. To the north the Um Disi chain rises to heights of from 1200 to 2000 metres, consisting of smooth granite with rounded, nipple-like, or precipitous summits. Every mountain, in fact, possesses a characteristic feature of its own. Running round the edges of these ranges are low dark hills, while to the south of Um Disi, on the other side of the Um Yessar valley, these form a respectable ridge.

The water pool of Um Disi is up a narrow gorge, the granite cliffs rising steeply on both sides of the valley while the ravine itself is filled with large boulders.

Um Disi Pool. The pool is approached by a steep smooth slope down which a small stream of water is constantly trickling, enabling green masses of fresh-water algæ to flourish there; it lies transversely to the gorge, and being over 9 metres long, 6 metres broad, and probably 3 metres deep, it may justly be described as inexhaustible.

There is also a smooth sloping wall of rock on the northern side, down which flows a continual stream of water, and higher up the valley are some shallow basins filled with reeds. Vegetation of all kinds is very abundant in the neighbourhood, especially "bsilla." Seyal trees are numerous, "markh" (*Leptadenia pyrotechnica*, Decn.) also occurring in large bushes. Besides these, "gurdi" (*Ochradenus baccatus*), a large mignonette-like plant, and "ghalgai" (*Dœmia tomentosa*) with heart-shaped leaves and a milky bitter sap, are noticeable, while many beautiful white-stemmed "moin" trees occur amongst the boulders. In the pool itself grow masses of reeds or "disi," and the name is evidently derived from their occurrence. Amongst the plants collected here, Dr. Schweinfurth has recognized the rare sedge *Schœnus nigricans*.

Animal life, too, is abundant, blue dragon-flies skimming the water, in which water-beetles are plentiful, small lizards dart from rock to rock, and beetles cross the path at every turn. Moths, too, at nights swarmed round the lights, and the holes of jerboas and jerbils were of frequent occurrence in the gravel plateau at the foot of the Um Disi gorge.

In the hopes of obtaining a good point, an ascent of one of the Um Disi peaks was attemped, but it was found to be separated from the main wadi by several ranges and deep valleys.

From the summit of the hill the granite mountains were seen clustered to the east, the dark range of Fatiri el Iswid passing behind them to the south-east, with Jebel Abu Harif beyond. To the west lay the dark foot-hills, the centre of the view in this direction being a sandy plain. The general trend of the principal ranges of Fatiri el Iswid appears to be south-west, but they send off several marked north-west spurs.

From Bir Um Disi a three days' traverse was made into the centre of the mountain ranges to the east. After traversing granite ridges, and passing through an opening in a low range of dark green colour, the road runs through a narrow and very picturesque gorge, bounded by steep granite mountains. This valley, Wadi Atilmi, is especially characterized by the abundance of its vegetation, no less than thirty plants having been obtained here.

Wadi Atilmi.

Bir Hedeba. The most important well here is up a side valley, Bir Hedeba. The Wadi Hedeba, a mere gully, winds considerably, and there is at one

turn a small and dirty pool of water, evidently much frequented by Ibex ("tetel") and bordered by wild fig (*Ficus pseudosycomorus*). The drinking well itself is higher up in the granite, the water occupying a narrow fissure about 2·5 metres long, and 1 metre deep in the deepest part, while owing to the steep slope to the water, it is not liable to pollution by animals. There was, at the time of the visit, enough to fill four or five fantasses, viz. 200 litres, but after rain, water must be abundant here, judging from the number of waterholes filled with moist sand.

The main valley winds continuously until it widens at a point where a long dark ridge extends on its north side. Water is reported as existing up the side valley running to the west of this ridge, the wadi also being regarded by the guide as the dividing line between the Kohela and Gattar-Um Disi ranges. Only small wadis enter Wadi Atilmi to the north, but to the east it breaks into three branches, the main valley running north-east and ending blindly against the foot of J. Atilmi. To the north and north-west rise granite mountains of manifold forms, the long, dark, sloping ridge of Kohela, over 1500 metres high, contrasting strongly with these. To the north-east the mountain system is simple, consisting of a single range, and here rise two granite hills with a pass between them, Jebel Atilmi, this range having grand precipitous sides and running south-east in the direction of El Shayeb.

Ascending the pass, a very rough and stony climb, the watershed is reached, the relations there observed being as follows:—

The pass is evidently due to the wearing away of a vein, as on its eastern side a gully runs in a straight line at a very steep angle, and a valley on the other side runs through two ranges to the sea, the second or higher range containing the two peaks of Abu Moin and Abu Mattur (probably identical with J. Mattur, seen from the Coast Plain). A big valley running parallel to Wadi Atilmi is Wadi Minfeih, which opens out into the sandy plain shortly to be mentioned.

The two other branches of the wadi are Wadi Um Raera and Wadi Ghoza, the former of which takes a southern bend and enters the latter.

Between W. Atilmi and Wadi Ghoza the country consists mainly of low granite hills, behind which the high spurs of El Shayeb are visible.

Bir Rihueshid

Just at the point of junction of the last two wadis, is another well, Bir Rihueshid, situated up a small side valley. This lies in a gully (resulting from the wearing away of a diabase vein), across which a large granite boulder has fallen, its shade protecting the water, which is in a fissure 1 metre deep where visible, continuing under the rock for a metre or so. Owing to the steepness of the slope, the water is unapproachable by ibex, and is very good for drinking purposes.

Watersheds of Central Range.

While the main watershed is formed by the Atilmi range, the head of the Minfeih pass, the El Shayeb range, and the high ground of Wadi Abu Abid, south of El Shayeb, a secondary watershed runs across the head of Wadi Ghoza, and continues in the Abu el Hassan chain, separating the waters which drain into Um Disi, etc., from those which drain south-westward into the Fatiri el Abiad and Fatiri el Iswid valleys. At the head of Wadi Ghoza is a break in the mountain system, which on the east is only composed of low granite hills, but on the west is formed by the high granite ranges of Abu el Hassan. The road through this break runs into a wide sandy plain, whose surface is only broken by a few ridges due to dykes. The plain slopes rapidly from the north and east towards the south and west. It is bounded on the north-east by the El Shayeb range, on the north and north-west by the Abu el Hassan group, on the west and south by the dark ranges of Fatiri el Iswid, through which runs a wadi draining into the Nagateir Plain, on the south-south-east by the isolated ridge of Abu Harif, and on the south-east by the longer range of Abu Hamra.

Five roads cross this plain, one, bad for camels, running across a pass to Wadi Minfeih, and thus indirectly communicating with the plain north of the Gattar and El Shayeb district, *i.e.*, Wadi Belih; a second runs to the east of Abu Hamra leading to the fertile valleys of El Shayeb, and the southern road through Um Digal (see p. 39); a third runs into Fatiri el Abiad west of Abu Harif and a fourth leads by a valley through Fatiri el Iswid to the Nagateir Plain. The fifth is the one leading through Wadi Ghoza to Atilmi.

Boundary between Maaza and Ababda.

Though the true Maaza and Ababda boundary is apparently the main road between Qena and Qosseir, yet the latter tribe have now advanced their frontier to the line of the Fatiri el Abiad road, and appear to be gradually limiting the Maaza more and more to districts north of Dokhan.

Wadi Ghoza has evidently been an old road, probably Roman, as on small mounds are erected low stone huts, with the flat stone arch so common in Roman buildings.

The granite hills here are also traversed by east and west gullies with precipitous walls, resulting from the decomposition of diabasic dykes. Although this mountain region has been mapped by the Survey, the time allotted has not permitted of the satisfactory delineation of a district which mainly consists of rugged mountains rising 1000 metres above the narrow and tortuous valleys at their base. The only attempt to portray this complex neighbourhood which at present exists is the map by E. Floyer, published by the Intelligence Department, London, entitled: "Part of the Eastern Desert of Egypt from Gimsa to Keneh, 1887."

The points especially brought out in it are the presence of this great square mountain block, which forms the most prominent of its features, the position and relations of the Minfeih defile, and of the summits of El Shayeb, Um 'Anab, and Hamra, together with the sandy plain to the south-east of the mountain mass. On the other hand, viewing the map critically, it is probable that a more detailed survey will considerably modify the direction of the principal interior valleys, while the absence of figures indicating mountain heights leaves the reader without any clear idea of the relative levels. Fortunately, the Admiralty chart shows that the main summits of the range rise over 2000 metres above sea-level, while in addition there exist photographic records by Buxton*, showing the northern face of the Gattar range seen from Dokhan, and also containing a good view of the Abu el Hassan hills seen from Um Disi. The wall-like character of these hills is also well-shown on the panoramas and sketches prepared by Cooke.

A large amount of geographical information has also been brought together by Schweinfurth,† who studied the outer borders of this central massif, but does not appear to have visited its interior valleys.

Traverse from Um Disi.

Returning to Um Disi a traverse was made to the west up Wadi Um Yessar, which ‡ runs close to the Um Disi chain in a northerly direction for about two kilometres, when it takes a sharp western bend and opens into a plain crossed by long parallel ridges. At first it runs between dark low hills, the range on the south forming a conspicuous summit near Um Disi.

The country to the west of the central mountain massif is typical ridge or dyke country, long sharp ridges usually not more than 50 metres high running parallel to one another, mostly in an east and west direction. One of these is especially prominent on account of its deep red colour.

The track to W. Gattar winds round the edges of the hills between the east and west-trending ridges, and low dark hills of basic rock, above which tower fine granite peaks to the east. It finally traverses a low ridge, and enters a broad valley, Wadi Gattar, which running in an east and west direction issuing from the mountains, after various windings joins Wadi el Atrash. Several other wadis, all rich in vegetation, bear the same name, and after meandering between low

Wadi Gattar.

* On both sides of the Red Sea.

† "La terra incognita dell' Egitto propriamente detto," *Esploratore*, anno II, 1878, Milano.

‡ Yessar is apparently the Maaza name for the Moin tree which, though absent in the valley itself, is common in the small side gorges of the higher mountains. Just where the wadi takes a sharp south-west bend, it is rich in prickly bsilla bush, and all round the edges of the high mountains, this plant seems to be extremely common.

ridges, join the El Atrash system, while the confluence of the two valleys forms a well-marked plain, across which a series of hog-backed ridges runs in an east and west direction.

Gattar pools.

Water occurs in W. Gattar some distance up the valley in a series of pools in the mountains, the supply being usually abundant. In the wadi is a small Roman building,* which was full of broken pottery but otherwise contained no features of interest. Here "seyal" and "bsilla" are common, the latter on the north of the valley being replaced by bushes of "shia."

From Wadi Gattar a western track crosses low ridges and wide wadis coming down from the Dokhan range, the high ridge of which rises to the east, while between it and the Wadi el Atrash the hills become lower and lower, though usually showing the long sharp rising ridge and rounded conical summit characteristic of hills formed by doleritic rocks in the Eastern Desert. On the west rises a bold range of red granite hills, Jebel Abu Hamra, which bounds the wadi with precipitous sides, in places rising 300 metres above the plain.

Ascending Wadi el Atrash the valley begins to narrow, the lighter coloured range of El Atrash and the granitic spurs of Abu Harba approaching one another, while the opening of Wadi Um Sidri is seen to the east, this valley soon becoming lost among dark foot-hills. On the west, too, opens a wadi, which bends round J. el Atrash, and forms a direct road past Jebel Sobeir to the Gharib district. This road is at present untraversed. The nomenclature of Schweinfurth's map of this district was a source of some confusion in making arrangements with the guides. Jebel Um Sidri is marked as one of the most important peaks in the district, but all questions failed to confirm the existence of such a hill, the answer always being that Dokhan and Um Sidri were like Um Disi and Gattar, names for the same chain and for the same reasons as previously stated (see p. 13). From Schweinfurth's description and its position on the map, it is evident that his Jebel Um Sidri is Abu Harba, which had already been pointed out on the previous traverse from Abu Had by the trustworthy guide Hamed Assawalla. The mistake is easy to understand, as from the point of view taken, Schweinfurth would have seen the summit of Abu Harba over the ridges to which the name Um Sidri is given, and his guides would probably have named the latter. The Jebel Harba of Schweinfurth also required re-naming, being really Abu Marua. A stay was made at the foot of Abu Harba to enable an ascent of the mountain to be made,

Jebel Abu Harba.

* Described by Schweinfurth.

the intention being to use it as a plane-table station, and at the same time take hypsometer observations to settle the question at issue as to the height of the mountain, Schweinfurth regarding Nares' figure of 5860 feet as too low, and himself assigning 7000 feet in a note appended to his map*. Water-holes are numerous at the foot of the mountain, but, owing to prolonged drought, were empty, and the camels had to go to a well in Wadi Abu Marua to fetch water, which was of a somewhat unpleasant taste. The original programme was completely spoilt by a sand-storm, which raged the whole day, and in consequence the ascent of the mountain was made by Hume alone.

The lower granite foot-hills are very precipitous, but gullies have been formed along the direction of the diabase and dioritic dykes which materially assist the climber. Beyond being somewhat steep, the remainder of the ascent was comparatively easy, advantage again being taken of a dioritic vein which led straight to the ridge. From this point the ascent of the main peak without ropes, etc., was found to be out of the question, it rising as an abrupt granite precipice some 60 to 90 metres above the col.

The reading of the barometer on the ridge gave the height as 807 metres above the base, the total above datum at Qena being 1475 metres. Adding 80 metres for the main peak judged by proportion = 1518 metres, and about 90 metres for height of Qena Slaughter House, the starting point of the expedition, makes the probable height of the mountain a little over 1600 metres, therefore tending to confirm the results obtained by Nares.

The view (seen in a preliminary partial trial ascent on the previous afternoon) embraces a sea of hills extending as far as Dara and Gharib, the ridges and valleys trending roughly east and west. On the east of J. Abu Harba runs a small valley, separating it from the dark hills of the Um Messaid group and a little to the south-east opening into Wadi Um Sidri, which here has a meandering course. The dark hills of the Dokhan-Um Sidri range extend to the south-east as a high ridge. Abu Harba (the father of spears) is remarkable for the huge dykes which cross right over the crest, one red felsite dyke standing up like a broad red wall being a very conspicuous object, the gullies, too, as has been remarked, resulting from the wearing away of the basic rocks.

Returning southward the track for a time ran down the fertile valley of El Atrash, but afterwards meanders among low hills, dykes and ridges,

* Schweinfurth does not apparently give the method adopted by him in determining the heights of these mountains.

Wadi Abu Hamra.

till it is joined by Wadi Abu Hamra, a pebble-strewn, bare valley, near whose junction a small side valley to the west was pointed out by the guide as being a road to Wadi Hamed. A hill was ascended at the south end of J. Abu Hamra, and from it the whole region west of Wadi el Atrash was again seen to be composed of a number of valleys and ranges, trending roughly east and west. In the distance to the north-east was seen the solitary peak of Mellaha, and further to the west, the dark range of Sobeir and the varied summits of Gialla. About 20 kilometres north of our position, extended the jagged, presumably granitic ridge of Guberat Ghanam, while between Abu Hamra and it lay innumerable parallel ridges. Two wadis carry the westward drainage to Wadi Qena, viz., Wadi Hamed and Wadi Sobeir, but these have not been visited.

Jebel Um Ajraf.

To the west of Abu Hamra was a dark range, Jebel Um Ajraf. The character of the country is here briefly described, but this western side of the Red Sea Hills does not appear to have been yet visited by any geographer, though the mapping of the central road from Sobeir will probably yield results of much interest.

Wadi el Atrash.

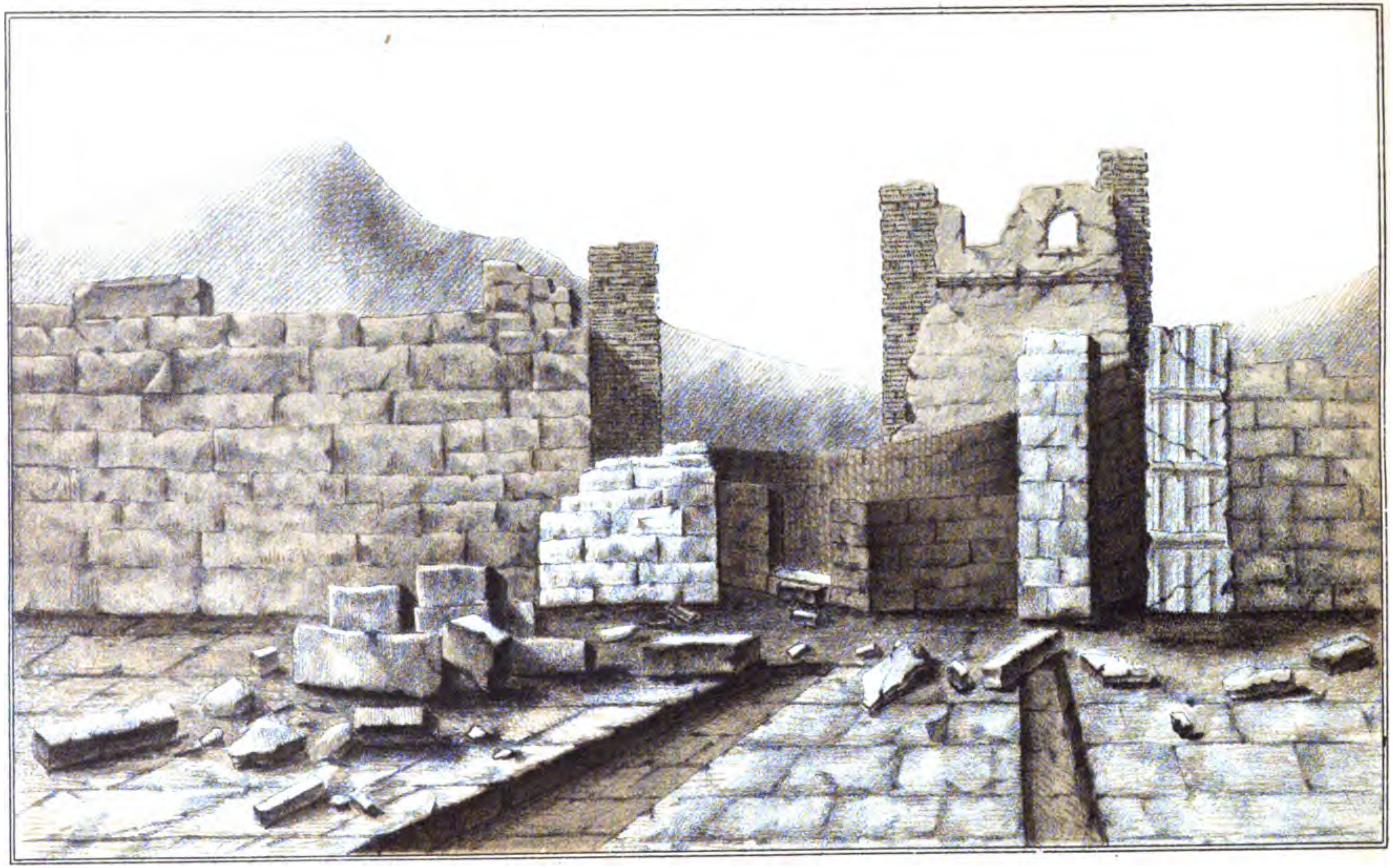
The topographical problems presented here are interesting, Wadi el Atrash being the main member of a longitudinal valley system which runs nearly due north and south, bounded on the northern part of its course by steep and precipitous mountains, and in its southern portion breaking through the lower hills in such a manner as to suggest that it also owes its origin to the faults or rifts, which have played so important a part in Egypt, while the view from Abu Harba suggests the possibility that a longitudinal fissure practically bisects the Red Sea chain.

The same parallelism is shown by Wadi Minfeih on the eastern side of the Gattar mountains, the result being the production of the remarkably square massif of Um Disi, Atilmi, etc.

Main watershed.

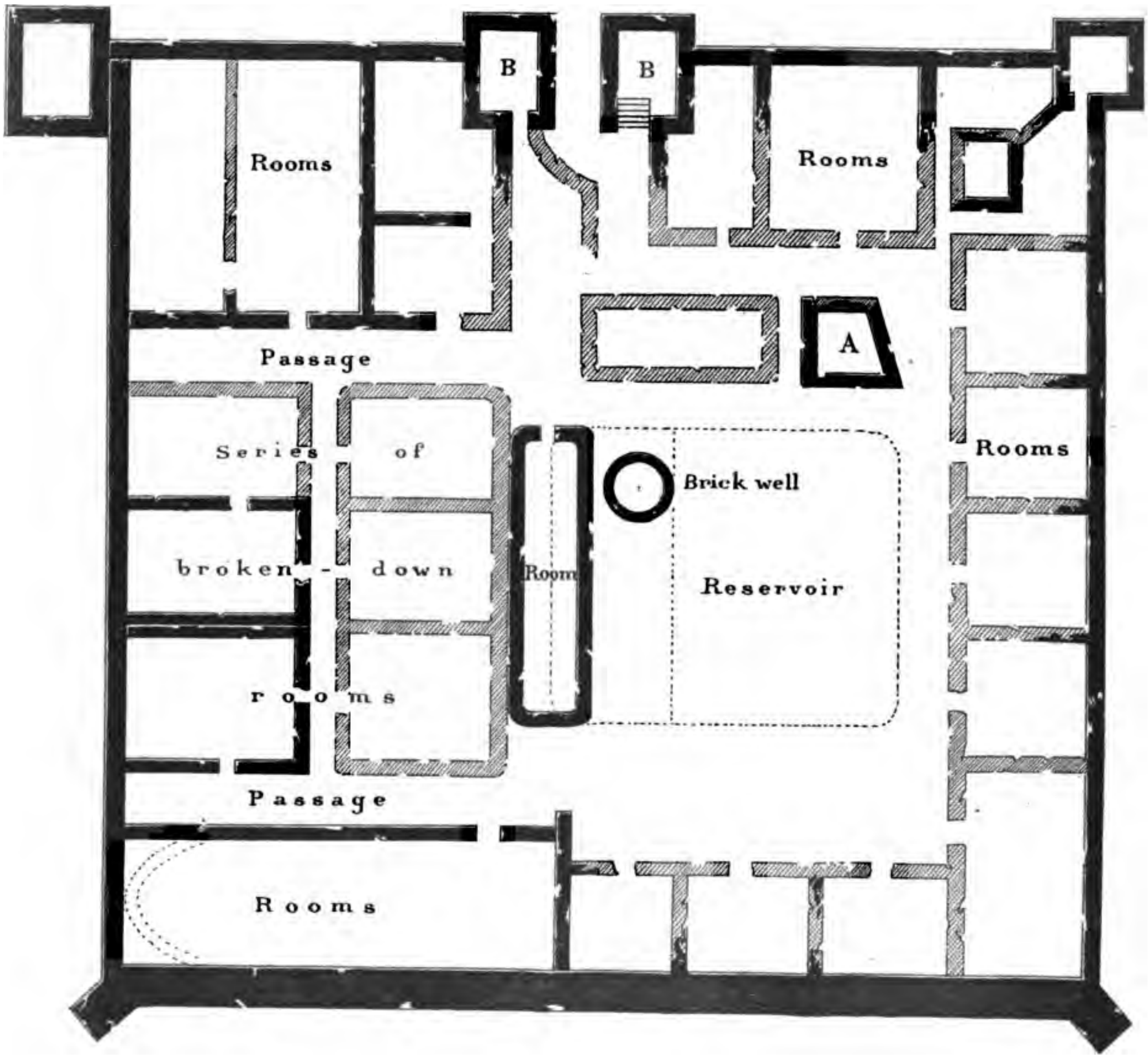
The main watershed running from El Shayeb is the cause of the steep Minfeih defile, and is then formed by the Atilmi and Gattar mountains, first changing from a north-south to an east-west direction, and again resuming the north-south direction, where it crosses the head of Wadi Belih by an insignificant ridge, beyond which it is continued in the peaks of Dokhan and Um Sidri. North of that point its course

*This result, of course, possesses the disadvantage of being based on observations made with a single aneroid, which many experiments have shown to be unreliable. The height of the camp at J. Abu Harba was determined by a chain of aneroid observations, made on the road from Qena to Bir Um Disi, and thence to the head of Wadi el Atrash, these being read at the same time every day so as to reduce the sources of error as much as possible. The height of the mountain above camp is the mean of the readings for ascent and descent respectively, Whymper having shown that such a mean closely approximates to truth, even with an aneroid. The difference in this case only amounted to 10 metres.



Roman fort of Deir el Atrash

Plan of Roman fort at Deir el Atrash



has not been further traced, but there is probably a low watershed in Wadi Um Sidri, the position of which requires determination.

Wadi el Atrash is one of the most fertile in this district, "markh" in large bushes being everywhere, while "bsilla," and "tagha" (a bushy crucifer with white flowers) are abundant, so that the valley is a paradise for camels. The foot of Abu Harba and Dokhan is a favourite locality for snakes, the horned viper (*Cerasites*) being especially common, while less poisonous varieties, especially a gray thin variety, called "asella" by the Arabs, were sometimes seen resting on stones. In addition, bees, hornets, lizards, and blue dragon-flies added to the life and movement. **Wadi el Atrash.**

In Abu Harba, ibex are evidently abundant, judging from the tracks, while W. El Atrash is famous among the Arabs for the number of its gazelle.

Here, too, hundreds of birds resembling the herons or egrets of the Nile Valley were observed travelling in the direction of Sinai.

From Wadi Hamra the track ran along W. el Atrash to the old Roman station of Deir el Atrash (see Plates VIII and IX). The stones of thewalls, though uncut, have the smoothed sides turned outward, the towers are of brick, cemented by mortar containing many pebbles, the brick itself being very porous and containing much silica. **Roman Station of Deir el Atrash.**

The well is still in good preservation, and in the rooms were found fragments of pottery (one piece with three black circles on it), pieces of imperial porphyry, verdi antico, and shells from the Red Sea littoral. A roadway led from here to the Deir in Wadi Um Disi. At the south-west corner is a well polished granite block (30 centimetres square in plan, rectangular in elevation, and about 10 centimetres high), which had been pierced by a wedge-shaped hole.

On the return to Bir Um Disi, after crossing the Um Yessar plain, where vegetation is poor, the party followed a rough track through the range running parallel to Wadi Um Yessar, so as to obtain a closer knowledge of the geology of these hills. Returning to Wadi Gattar, a low ridge separates the valley of that name from Wadi Belih, which runs in a north-east direction towards the coast plain. On the southern side of the valley rise bold granitic peaks 1500 to 1800 metres high, of varied form, and extremely precipitous, with a band of low dark hills resting against their flank ; on the north the latter are more numerous, and increase in height as they approach the high southern spur of the Dokhan range. At the first station on these low hills the rocks were magnetic. A low ridge separating Wadis Gattar and Belih forms the **Wadi Belih.**

watershed at this point, the latter being afterwards continued by the main peaks of the Dokhan range on the north, and by the eastward-trending granite range of Jebel Belih on the south. To the north of the road, the stratified appearance of some of the lower foot-hills is a very striking feature, due to the dolerite having been laid down in sheets. Good water is present up one of the side valleys under the Belih peaks, the name of the wadi being apparently Wadi Arradi.

There had been but little change in the flora on crossing the watershed, except that it was not so rich, and the plants seemed more withered. The principal plants were "seyal," "moin," and "markh." Further down the valley, among these dark hills, close to the open-

Roman Buildings.

ing of and in a tributary descending from Dokhan, runs a good Roman road (all the big stones in the wadi having been carefully cleared to both sides of a broad space), leading to a deir consisting of several buildings. On the south is a well-preserved building of two rooms, with thick walls of dressed stones, while along the west side of one of them runs a raised stone bench. The back is formed by a ridge of rock, two watch houses being also posted on each side of the valley. The main building has a curious low wall projecting opposite the doorway while inside is a central passage having four rows of rooms arranged on both sides, in one of which is a solid stone (granite) basin about 45 centimetres diameter and 10 cm. deep. At the end of the passage is a large chamber, entered by a door formed of two rectangular blocks, having a granite block across them forming a cross-piece (see Plate X) inside which is a well-cemented bath 4·8 metres square and 3 metres deep, divided by a low wall into two compartments a pipe at the south-east corner communicating with a broken reservoir outside the room. In addition pottery, blue enamel, and shells were met with. The road then continued up the valley to some dolerite quarries, the rock having been smoothed and polished above the probable water-level of the torrent during rain, and on the surface, small stone buildings were erected, the narrow entries having granite blocks on both sides with a cross-piece across them. There were stone seats in one chamber consisting of dolerite blocks about 0·75 metre long, resting on three roughly rectangular slabs of dolerite.

In front of the Gattar range, is a flatter rounded granite hill, Jebel Minfeih, the dark range running eastward between it and the low

Sala el Belih.

granite hills, one of which, Sala el Belih, is prominent on account of its greater height and rounded pyramidal form. The route lay through this granite region, the precipitous ridge of Dokhan, the Figari Berg of Schweinfurth, rising west of the low country with sheer cliffs facing

eastward. At El Beidia, the Romans have built a thick wall round a granite hillock, which would serve as a tower of observation, near by being a large ruined building which possesses no special features of interest. To reach the well known temple of Dokhan from this point a pass has to be crossed, the ascent being rendered easy by a zigzag Roman path, whose position is indicated by a small building present at the point where it begins to mount steeply. The road itself is stony and devoid of vegetation. On reaching the pass, an ascent was made by the south-east ridge to the second highest peak of Dokhan, the "H" of Schweinfurth.*

The main peak is slightly higher, but would probably not exceed 1800 metres. Unfortunately the ascent was not part of a definitely arranged plan, so no hypsometer observations were made, and time prevented the ascent of the main peak, which is easy from the valley on the opposite side. The result suggests, as Schweinfurth suspected, that the height given for Dokhan by Nares was too low. In the valley itself, on the other side of the range, are the temple, well, etc. The well has five pillars of rough stone cemented with mortar, on which rude drawings of ships, gladiators, etc., have been traced, while many travellers have inscribed their names here, those of Lepsius and Schweinfurth being prominent. A walk of smooth cement runs round the wall of the temple, which is approached by a flight of steps, but only a small part of the wall is standing, and the pillars have fallen in various directions. The architrave is broken in three pieces, each one bearing a portion of an originally continuous inscription. The altar is not flat, but curved, while a doorway, facing north, and part of a well-built wall, the compass bearing of which is 5° N. of W. still remain.

Temple and well at Jebel Dokhan.

Translation of inscription on temple:—

"For the safety and eternal victory of our Lord Cæsar, Trajan Adrian, absolute, august, and of all his house, to the sun, great Serapis, and the co-enshrined Deities, this temple, and all its appurtenances, Epaphroditus... of Cæsar... Governor of Egypt. Marcus Ulpius Chresimos, superintendent of the mines under... Proculeianus."

The blocks probably ran in sequence.

From here an ascent was made to the porphyry quarries, which are reached by a broad winding road, now much cut up by torrent gullies. On the right of the road, on a piece of raised ground were some small granite pillars, and in the path itself, a slab bearing an inscription was discovered by Hardwick, which possibly at one time had been borne

* An anæroid dertermination gave 1570 metres as the height of this peak, the principles of computation being the same as these adopted in the case of J. Abu Harba.

on the pillars. The presence of this record is of special interest, as the inscription is in Greek, opening with the words "ΚΑΘΟΛΗΚΗ ΕΚΚΛΗΣΙΑ" but Prof. Ramsay, of Aberdeen, to whom one copy was submitted by E. Quibell, states that there is not sufficient to form a connected translation.*

Along the path are several smooth stone platforms, possibly used for resting the pillars as they were brought down. Just below the quarries, there is a Roman building containing several rooms, the whole being built of stone; in the latter, many blocks of both green and red porphyry were lying about, some of them having marks on them.

Bir El Beidia. The El Beidia well is simply a depression in the gravel, and the water appeared to be very impure.

Continuing northward, the road traverses a grey granite region, which forms hills from 30 to 60 metres high, with rounded summits. The darker hills of the Dokhan range run to the westward, and parallel with the track, which finally enters the Wadi Adalla, a broad but short wadi running straight down in an eastward direction from the main chain, and opening out into the broad eastern plain. Wadi Adalla opens into the wide valley of Um Sidri, which is bounded on the east by a low gravel ridge, from which a fine panoramic view of the whole district is obtained. The series of panoramas were commenced here by Cooke, and for the general aspect of the country from this point reference may be made to Panoramas I, and II.

From Wadi Adalla the road ran up Wadi Um Sidri to a low pass between the gravel ridges and the granite hills, and at this point there is a low platform, a broken pillar, and the evidence of Roman quarrying, Wadi Um Sidri. the spot being marked on Schweinfurth's map. The main wadi opens north of the pass, running almost due east and west, and being a narrow gorge before it leaves the granite, but afterwards widening out between two low gravel ridges, which extend eastward in long tongues into the plain.

A low pass separates the Um Messaid valley from that of Um Sidri, the latter wadi being at this point bounded by precipitous cliffs. Wadi Um Messaid runs slightly east of north, receiving many side branches. On the west the dark porphyry ridge continues, rising into the higher peaks of Um Messaid and Kufra,† but the valley itself runs in the lower

* If circumstances permitted, it would be well if this unique memento of Christian influence at Dokhan were obtained for the Cairo Museum, as it now runs imminent risk of being swept away during one of the sudden rain-storms.

† See panorama I.

NOTE.—In this neighbourhood a large spiny-tailed lizard (*Uromastix*) which feeds on seyal, was met with, snakes also are abundant in the bsilla bushes, lying in wait for the birds, which are abundant in these valleys.

granite country, which is veined by east and west as well as north and south trending veins. The granite rising high into the hills on both sides gives the scene a characteristic red-brown colour.

Near the mouth of Wadi Um Messaid camel food was plentiful while the camels were supplied with water at the Kufra well, the road to which leads through a narrow gorge with steep granite walls, its direction having been in part determined by the wearing away of a diabase dyke. After one or two windings the valley broadens out on to a wide space, which, thanks to the enterprise of two Maaza Arabs, (one of whom, Awad, an old man of 70-80 years of age, was with Barron's party) had been in part converted into a palm garden, some of the date-palms being 4·5 to 6 metres high. The well itself consists of several water-holes, two of which contained water (slightly salt, but not unpleasant) at the time of the visit.

A question of Arabic nomenclature here materially altered the plans. Understanding that there were some interesting mines to be visited near Bir Mellaha, it was arranged to meet at that well. Knowing Mellaha mountain to be in the main Red Sea chain, it was concluded that the well was at its base.

Instead of this being the case, the party working in the hills had to leave them and cross the great plain, both the high and low ranges which drain into Wadi Mellaha receiving the same name, though the two are 20 kilometres apart, and separated by a wide expanse, through which the drainage meanders in shallow water-courses. This is but another example showing that in the Arab nomenclature drainage ranks first. The plain itself is comparatively bare, broken only by low ridges of gravel, and otherwise devoid of interest, but a fine view of the mountain district is obtained (Panorama II.,) and the further remarks on the character of the Red Sea Hills will be based on the observations made from this point.

Before leaving the Dokhan district, reference must be made to Dr. Schweinfurth's map of the country, published in 1877-78, which is the present standard, bringing out the main features in a striking manner, and dealing in detail with the valleys adjoining the porphyry mines. The main criticisms have to do more especially with questions of names and heights, and have already been referred to, the writers' aneroid results leading them to agree with Schweinfurth as regards the height of Dokhan, and with Nares in respect to Abu Harba, while careful testing with different guides renders the change of Om Sidr and Abu Harba to Abu Harba and Abu Marua respectively, a necessity.

medium ridges alternating with sandy wastes. The north of Wadi Dib is bounded by a high porphyry chain, Jebel el Urf, with summits of over 900 metres, which is separated from Mongul, by a valley which does not appear to have any special name, the guide describing it as part of Wadi Mongul.

At the head of Wadi Dib is a point where four tracks meet. The southern tracks (for there is no well-defined road) run between the low ridges and across small sandy plains to J. Sobeir; the western one also follows up Wadi Dib, cutting across low dark-red ridges, till it reaches the watershed. From thence it descends, still among low granite hills, to Wadi Qena, which at this point is bounded on the west by the high limestone plateau cliff, with low foot-hills at the base. The eastern is the track the party came up, and the northern, which leads behind Dara to Gharib, was the road subsequently followed. Almost opposite the camp pitched at the crossing of these roads, was a yellow hill, which, on examination, proved to be composed of grey marble and slates, and is but one of the foot-hills extending from Jebel el Urf while porphyry fragments are very abundant among the pebbles. From a point behind the camp it is seen that the J. Mellaha, Sobeir, and some of the higher Dib hills, form a high series running more or less at right angles to the main range, to the north of which is only a sandy plateau crossed by low ridges. Towards Jebel el Urf northward, the Dib hills again rise, the drainage of a very wide district passing into Wadi Dib, which is one of the most important drainage areas in the district. The northern road first passes between high spurs running west-south-west from the El Urf range, and then opens out into a lower country of granite hills. El Urf itself consists of three parallel ridges, the highest of dark purple colour and of bold outlines, the second, a yellow-coloured range, parallel to the former, and the third, a low, dark doleritic range. The road, after a sharp wind, passes through a gap in these hills, which rise steeply on both sides, and then descends rapidly to Wadi Dara, which runs as a wide valley through low ridges of granite, etc. The crest of El Urf to the west of the road was ascended, and it was then seen that the main range continues about 6 kilometres westward, after which, low granite country lies between it and Wadi Qena. Wadi Dara, is, like Wadi Dib, a system of valleys draining from the watershed, which run north-west in the low granite coutry. This drainage system is bounded on

Marble near El Urf.

Jebel el Urf.

Wadi Dara.

NOTE.—For the circular trip round El Urf and Dara to Gharib the guide was Rashid Aid, now at Gharib, who was fully acquainted with the old mines and marble district, and proved a very efficient help.

... wastes. The north of Wadi Dib ... Jebel el Urf, with summits of ... from Mongul, by a valley which ... the guide describing it as

... where four tracks meet. The ... defined road) run between ... to J. Sol ir; the western ... across low dark-red ridges, till ... it descends, still among low ... this point is bounded on ... with low foot-hills at the base ... come up, and the northern, which ... the road subsequently followed ... the crossing of these ... proved to be composed ... of the foot-hills extending to ... Urf ... very abundant among the ... it is seen that the J. Mongul ... Dib hills, form a high series ... to the main range, to the north of which ... crossed by ... ridges. Towards Jebel el U... again rise, the drainage of a very wide district ... which is one of the most important drainage ... The northern road first passes between ... from the El Urf range, and then ... granite hills. El Urf itself consists of ... of dark purple colour and ... coloured range, parallel to the former, ... dolerite range. The road, after a sharp ... these hills, which rise steeply on both ... gradually to Wadi Dara, which runs ... of granite, etc. The crest of El Urf to the ... ended, and it was then seen that the main ... metres westward, after which, low granite ... Wadi Qena. Wadi Dara, is, like Wadi Dib, ... from the watershed, which run north- ... This drainage system is bounded on

... El Urf ... to ... the guide ... Pasha ... with the ... and marble district, and ... a very

VIEW OF JEBEL GHARIB AND GUEREB SEEN FROM THE SUMMIT OF ONE OF THE DARA PORPHYRY HILLS.

the south by the El Urf and Mongul chains, while its wadis cut straight across the Dara ranges, whether granitic, felsitic or porphyry. This points to the high ground having once been where the low granite ridges of Wadi Qena now are, denudation having for some reason been more active on the western side of the Red Sea Hills, has now had an opposite result, the higher ground lying more to the east. On the the of a branch of Wadi Dara, behind the low red and grey granitic and dioritic ridges, rise higher dark purple hills with flat summits sloping eastward, due to the dip of the felsitic, etc., rocks composing them.

The main track to J. Gharib ran almost due north in the low ridges, with the felsitic hills on the west. The granitic foot hills are at times over 90 metres above the valley in this neighbourhood, while the felsitic range rises 180 or 210 metres above the same point. To the east of the road, succeeds ridge after ridge of grey granite, running parallel with the main crest of Dara, which faces the plain with a precipitous front. At the head of one of the Dara branches, running down from a semicircle of high dark hills to the east, are low ridges of diorite, in which are old Roman workings for some ore now exhausted, probably copper, as a blue-green copper silicate, chrysocolla, in places still lines the vein. At the base are some round stone buildings of the usual type. From the summit of one of the felsite hills, on which Cooke made a sketch of Guereb and Gharib*, it was seen that the Dara system consisted of two sets of valleys, one transverse, or east and west, the other longitudinal, or parallel to the direction of the ranges. The transverse wadis are usually broad and rich in vegetation, with no very marked fall; the longitudinal valleys, on the contrary, fall steeply southward, are very pebbly and bare, and are separated from the transverse valleys by short steep passes, like the one shown in the photogravure. The height of the hill ascended was 234 metres above camp. The Gharib track continued up a longitudinal valley to the northward, but the pass at the end being too steep for the baggage camels, these were obliged to make a detour to the west while the party crossed the pass on foot. Here Jebel Guereb rises in steep precipices on the opposite side of a wide valley, Wadi Guereb, which has the characters of the transverse valleys. The country north of this point is outside the present area, and will not be discussed here in detail.

Copper silicates near Wadi Dara.

Having thus considered the Red Sea Hills in such detail as is possible, it will now be advisable to view them in broader outline. One feature

Relations of transverse valleys.

*See Photogravure No. 3 View of Gebel Gharib and Guereb, etc.

which will probably come out strikingly in the completed maps is the distance to which the transverse valleys extend behind the main range, this being especially the case with the northern wadis which have their sources in low foot-hills close to Wadi Qena. These transverse valleys have another point in common, viz., their parallelism, all of them running more or less north-east, this being very well shown on Zittel's map, while in addition many of them cut right across the lower parallel ranges to the east. Attention has also been called to the striking character of the north and south trending longitudinal valleys, which sometimes, as in the case of El Atrash, extend for many miles, and enable high mountain ranges, such as Gharib and Dara, to be traversed from the back, or western side. Owing to the crossing of these transverse and longitudinal drainage lines, there is a tendency for the production of rectangular and square mountain blocks, the most notable of these being undoubtedly the Um Disi-Gattar massif while Gharib also has the same peculiarity.

Principal mountains of Northern Red Sea Hills.

Western Red Sea Hills.	Eastern Red Sea Hills.
Jebel Guereb 1,047 metres. Jebel Dara (porphyry). Jebel el Urf. Lower hills of Jebel Dib. Jebel Sobeir. Jebel Gialla. Jebel Guberat Ghanam. Steep but unnamed E. and W. ridges. Jebel el Atrash. Jebel Abu Hamra.	Jebel Gharib 1750 metres. Jebel Dara (granite) 1075 metres. Jebel Mongul 973 metres. Jebel el Adid el Gadan 1131 metres. Jebel Mellaha 1357 metres. Jebel Miuselman 1067 metres. Jebel Abu Marua (1573 metres) and Jebel Kufra. Jebel Abu Harba (1787 metres Nares) and J. Um Messaid. Jebel Dokhan (1830 metres Schweinfurth) and J. Um Sidri.

The height obtained for J. Mongul by the Admiralty was almost identical with that of the Survey, the aneroid being used, the figure for J. Gharib * also agreeing closely in the two cases. On the other hand J. Abu Harba was lower according to the Survey (1616 metres) while the result obtained for Dokhan agreed with that given by Schweinfurth. The above list includes all the most important summits in the Red Sea Hills, and speaking generally the hills on the western side are uniformly lower than those on the east.

* "Report on the Petroleum," of Ras Gemsa and Gebel Zeit, pl. 5, and pp. 6, 7.

Considering the extent of country and the height of the hills, the water-supply is very poor during dry seasons, but after rain, the many basins in the granite become filled. The best supply is in the high hills round Bir Um Disi, where, in addition to the large pool mentioned, the smaller basins of Gattar, Hedeba, and Rihueshid are only a short distance away. Further north, the artificial well of Beidia, at the foot of Dokhan, yields a very poor supply, and water is brought for caravans from a valley at the foot of the Gattar range. **Water-Supply.**

On the western side of J. Abu Harba are many waterpools, empty when visited, water having to be brought from the foot of J. Abu Marua. On the eastern side of the range, the well and palmgrove of Kufra shows how the water-supply might be improved by private enterprise.

In the district lying between Jebels Abu Marua and Mongul standing pools are very scarce, and on the western side are only present at the foot of J. Sobeir, but at J. Mongul itself there is a small hole 2 to 3 metres deep in a ravine but the two parties exhausted the small supply, and the main camp had to be established near Dara, whose well has been described and figured by Mitchell. The only other well known to the writers in the mountains is Bir el Gharib.

W.F.H.

2. *Red Sea Hills South of Lat. 27° N.*—Before commencing the consideration of the Red Sea Hills, south of lat. 27° N. the main watershed may be briefly viewed as a whole. It has already been stated that in but few cases does the water parting north of lat. 27° N., agree with the higher summits, such bold ranges as Gharib, Dara, and Abu Harba lying either east (the two first named) or west of this line of division. Indeed, speaking generally, the watershed as far as traced follows secondary ridges, or meanders across lower dyke country except in the Dokhan range, where it is formed by the main crest. South of Wadi Belih, this general character no longer holds good, the precipitous wall, towering 1000 metres above the valley, becoming the divide, which at first runs east and west in the Gattar-Belih range, then suddenly bends at right angles to form the bold heights of Atilmi, only once more to suddenly bend eastward, so as to include the lower spurs of the El Shayeb range, though the main mountain-mass of the latter lies to the east of the parting. This remarkable double rectangular twist is one of the most striking of the topographical features in this district, and the parting is only traversible for camels at one point, the pass of Minfeih, which itself involves some difficulty, as described by Lepsius. South of lat. 27° N., the watershed **Main Watershed largely distinct from highest mountain line.**

meanders across low dyke country in an inexplicable manner, trending in the main south-west and apparently avoiding most of the principal hill-systems.

South of the line of hills which embraces the summits of Fatiri, Abu Harif, Abu Hamra, and Um 'Anab, the Red Sea Hills disappear as a continuous range, the country consisting of a maze of low hills out of which rise isolated crests, which are conspicuous for many miles. Through this region meander broad valleys, on the western sides of the watershed having a westward direction until they meet the plains previously mentioned, and then draining round J. Abu Had or through Wadi Gareya into Wadi Qena.

The principal valleys west of the watershed are as follows, beginning from the north:—

I. Wadi Fatiri and Abu Zawel.
II. Wadi Abu Shia.
III. Wadi Markh.
IV. Wadi Jidami.
V. Wadi Hammama.

Wadi Fatiri and Jebel Fatiri el Iswid.

I. *Wadi Fatiri.*—From the point where Wadi Fatiri debouches into the Fatiri plain the foot-hills run away to the south-east and finally merge into the low hills occupying the country between this point and Wadi Markh, while to the north they gradually close up and finally disappear in the neighbourhood of the road to Bir Um Disi. As this wadi leaves the hills it passes through a narrow, vertical-sided gorge in a steep ridge formed by an intrusion of a red columnar rock in the surrounding dark-coloured hills. Following up this drainage line, which is also a well-marked camel track, the road bends in an east-north-east direction towards Jebel Abu Harif and Um 'Anab, the wadi varying in width from 150 to 500 or 600 metres. For the first 3 kilometres the north side of the wadi is bounded by the steep-sided black chain of Jebel Fatiri el Iswid which rises from 152 to 244 metres above valley-level, and afterwards bends off in a north-easterly direction, while a little further to the north another range 122 to 152 metres high stretches away in the same direction. At the point where the wadi leaves the ridge of Fatiri a small mass of hills, ranging in height from 76 to 122 metres, forms the northern boundary of the valley, and here a small tributary joins it. On the southern side the boundary is formed of low black hills, which extend as far back as the eye can see, being broken only by a low ridge of granite which runs more or less parallel with the wadi. This country is practically a plain in places, with low knolls scattered over it, none of the hills, except the granite ridge, exceeding 107 metres in height, the latter being 153 metres high. A little further

on, the wadi entered a district of low parallel hills, the latter being due to dykes of a red rock, which being harder than that of the main mass, stood out in relief and formed ridges, which in section resemble an isoceles triangle with truncated apex.

Ruins at Fatiri.

A little higher up on the south side of the wadi, and a short distance away from the road, a few ruins of huts were seen, which probably belonged to miners of early times. The walls of those which were still intact were about 1·5 metres high, built of dry rubble, and had each a small entrance 1·3 metres high, which in many cases still had the slab which acted as lintel. Not a few of these huts had a small recess built into the wall about 1 metre wide and 0·2 metres deep.

Beyond the dyke country, the Fatiri el Iswid range again approached the wadi, being separated from it by a mass of low hills about 60 metres high. The highest peaks of this range rise to over 800 metres above the valley, and their base is beautifully striped by veins of the red columnar rock previously mentioned, which contrasts well with the dark green colour of the main hill mass. At their base is a mass of low foot-hills under 60 metres in height. At this point there is no distinct boundary to the wadi, which may be considered as extending up to the base of the hills. Higher up a wide side-valley enters the main one on its southern side, the former being thickly covered with plants (principally "bsilla and bowal"), which in spring time make the floor a mass of green as far as the eye can see.

As Jebel Abu Harif is approached, the hills on the south side of the wadi rise to about 130 metres or so; while on the north is a large range running slightly east of north, which is about 750 metres high. On the south side the hills decrease in height as they recede.

Jebel Abu Harif.

This hill rises out of the surrounding low hills and towers above them in a most majestic way. It consists of a granitoid rock which weathers in such a manner as to form precipices and cataracts in the gullies which seam its sides, and in consequence its ascent is rendered both difficult and dangerous.

But the view from the top well repays the hard labour of the ascent. The highest summit consists of a rounded, overhanging mass of coarse granite which seems very unstable on account of the narrow base on which it rests. In shape the ridge is more or less rectangular, its northern and eastern sides descending in almost sheer precipices, while the remaining two are a little less abrupt in their angles. From the summit looking westward, the ranges of Jebels Abu Had and Arras, and under favourable atmospheric conditions, the cliff on the west bank of the Nile can be seen; while to the east the sea is plainly visible over the top of Jebel Barud, with Um 'Anab in the foreground.

Away to the south the Jarra-Jidami-Missikat el Qukh range forms a prominent feature of the landscape; while on the north Jebel el Shayeb—the father of the hills—towers head and shoulders above Jebels Um Disi, Dokhan, and Gattar.

A wide sandy plain separates this hill from Jebel el Shayeb, Jebel Abu Hamra and the range previously mentioned, one of whose peculiarities is the way in which its drainage behaves. Instead of taking advantage of the small wadi which comes out at the foot of Jebel Abu Harif, it winds round from the southern side, and breaching the bounding hills further to the west, makes its way into Wadi Fatiri from the west side of the dyke country previously described. A little further up, Wadi Fatiri ceases to be the main road and passes off in the direction of Jebel Um 'Anab. At this point Wadi Um Digal enters from the east, and as the main line of route lay in that direction it was followed.

Wadi Um Digal

This valley takes its origin at the watershed, discharging itself into Wadi Fatiri, and receiving several small tributaries in its course.

Roman fort and well.

About 2 kilometres from its mouth there is an old Roman fort and well. The latter, which is 3·6 metres in diameter and 6·1 metres deep and lined with brick, is situated near the centre of the wadi. It used to be surrounded by a wall in which were a few openings, but it is now in a ruinous condition. No water was seen in the well, only a few plants growing at the bottom. At the eastern corner of the wall of the fort stands a watch-tower 7·5 metres high, built of dry rubble, but in very bad repair. On either side of the wadi the country is composed of low hills about 60 metres above the valley, gradually rising to the north towards Jebel Um 'Anab, and falling towards the south, only a few isolated peaks rising out of the general mass, serving to break the monotony.

There is a good camel track all the way up the wadi; near its head another path crosses it, running in an easterly direction, probably leading to Mons Claudianus or Jebel Um 'Anab, in the latter of which water is found. The wadi abounds in camel food of all kinds; many small lizards and a few snakes were seen, and numerous gazelle tracks were noticed. Ibex must also be abundant in the neighbourhood as a Bedawi brought a part of one to sell.

Watershed between Wadi Um Digal and El Bala.

At the head of the Wadi Um Digal lies the watershed between the Nile Valley and the Red Sea, 587 metres above the level of the latter. The line of water-parting here seems to follow a somewhat tortuous course; to the north it passes off towards J Um 'Anab, while southwards it bends towards Ras el Markh and Jebel Jidami, from whence it passes away to the head of Wadi Rieh.

Roman Columns at Mons Claudianus.

See p. 39.

Columnar Felsite in Wadi Sellimat.

See p. 45.

The following is the description of the upper part of this drainage system independently investigated by the other party working in the Red Sea Hills.

Wadi Fatiri is one of the most important drainage systems in this part of the country, for though running as a single valley throughout the greater part of its length, it is formed to the east by a number of feeders draining the high ranges of El Shayeb, Um 'Anab, etc. It was first entered by the parties from the south through a rocky gully which runs from the watershed, but to the north of which the southern branch of Wadi Fatiri spreads out into a broad valley running between dark hills about 100 metres high.

A short distance to the north it enters at right angles Wadi Um Digal coming from the east, or Barud direction. North of the junction the country consists almost entirely of low dark hills penetrated by red coloured dykes, while a short journey up a small valley and a climb over one of these ridges brings the traveller to the famous Roman Station of Mons Claudianus, which has been described in much detail by Dr. Schweinfurth * and was also visited by Wilkinson. A short examination of the ruins and quarries was made, three of the inscriptions being copied. In several of the quarries are columns in a nearly completed state, but still embedded in the rock, while in the valley itself near the buildings lie pillars 7, 5 and 10 metres long. Special reference may also be made to a large incomplete sarcophagus, which is lying on the side of the hill, having evidently been derived from one of the western quarries. It is 5·75 × 3 × 1·75 metres (approximately), the ornamentation on the outside being simple scroll work.

Mons Claudianus.

In the small temple are inscriptions of Nerva, and the altar, which was covered up with rubble, was cleared, one of its sides being inscribed with the name of Mons Claudianus, while an equally well-preserved altar standing outside is dedicated to Germanicus †.

The valley north of this station is wide, having a hard sandy floor, and is well supplied with vegetation, charcoal being made from the scattered "seyal" that is found all along this drainage line and in its tributaries. The high ranges of El Shayeb and Um 'Anab were next

El Shayeb.

* Schweinfurth, G. "Die Steinbrüche am Mons Claudianus in der ostlichen Wüste Ægyptens.', Zeitsch. Gesellsch. f. Erdkünde zu Berlin 1897. Vol. XXXII, pp. 1, 2, with map and drawing.

† Many of the inscriptions and altars are copied or drawn in Burton's voluminous notes, preserved among the manuscripts in the British Museum. The full inscriptions on the altar on the top steps are as follows. On the front: AN XII IMP. NERVA TRAIANO CAESARE AUG. GERMANICO DACICO. PER SULPICIUM SIMIUM PRAEF. AEG. At the back: FONS FELICISSIMUS TRAIANUS DACICUS. and on the left side in Greek: ΥΔΡΕΥΜΑ ΕΥΤΥΚΕCΤΑΤΟΝ TRAIONON ΔΑΚΙΚΟΝ. Another inscription reads: ANNIUS RUFUS LEG. XV. APPOLINAPIS PRAEPOSITUS AB OPTIMO IMP. TRAIANO OPERI MARMORUM MONTI CLAUDIANO.

examined. The former rises steeply (see Photogravure No. 4) out of comparatively flat ground, having the large sandy plain of Fatiri on the west, and a gentle slope down to the Red Sea on the east. The range runs east and west, and consists of two parts joined about midway by a saddle, its total length being about 12 kilometres. The eastern portion contains the main peak, which rises as a jagged cliff with a slope of from 50° to 60° from the valley, it being also deeply grooved by ravines, filled with large fragments of granite. This mountain, which is the highest summit of the Red Sea Hills—2164 metres according to the Admiralty chart—appears to be merely a thin knife-edge, and is stated by the Arabs to have been once ascended by an Ababda, who, however, took three days to get down again. The water-parting of the country corresponds with a line joining the peaks of El Shayeb and Um 'Anab, and is marked by a sharp drop of level to the east, the passage from the Fatiri to the Red Sea valleys having to be negotiated by camels with some care. The southern wadi running as a deep furrow full of vegetation at the foot of El Shayeb, is filled with terraces of gravel at its upper end.

Um 'Anab and its well.

Um 'Anab is a large isolated mass of oval shape and of rounded outline, its axis being N.E.-S.W.; it is considerably lower than El Shayeb (about 1600 metres) and at its north-east foot lies Bir Um Digal or Um 'Anab, said to be a spring, and yielding a good water-supply. This neighbourhood shares the reputation with Gharib among the Arabs of being one of the windiest spots in the desert, nor did it belie its character during this visit, violent north-west winds rendering astronomical observations almost impossible, these being at the same time accompanied by frost in the mornings and heavy cloud throughout the day.

Jebel Abu Hamra.

South-west of El Shayeb lies the long range of Abu Hamra, this like all the hill-masses in the district, rising steeply out of comparatively level ground, its sides having slopes of about 40°, with occasional smoothed and rounded surfaces such as are frequent in the whole granite region. To the north-west of this hill is the plain of Fatiri mentioned above, around which are a number of large isolated crests rising about 600 metres above the plain. All the drainage of the district west of El Shayeb flows to the Nile valley. While the main Wadi Fatiri runs through a narrow groove to the broad plain previously described, there lies to the south of it a hilly region, the road through which runs across a number of low cols and small tributaries of Wadi Fatiri which meander between dark hills that rise to a height of 280 metres above the comparatively flat surrounding district.

Jebel el Hadrabia and its ruins.

A small granite range at the eastern end is called El Hadrabia and contains pools where water collects after rain. In the centre of this area are ruins of ancient crushing

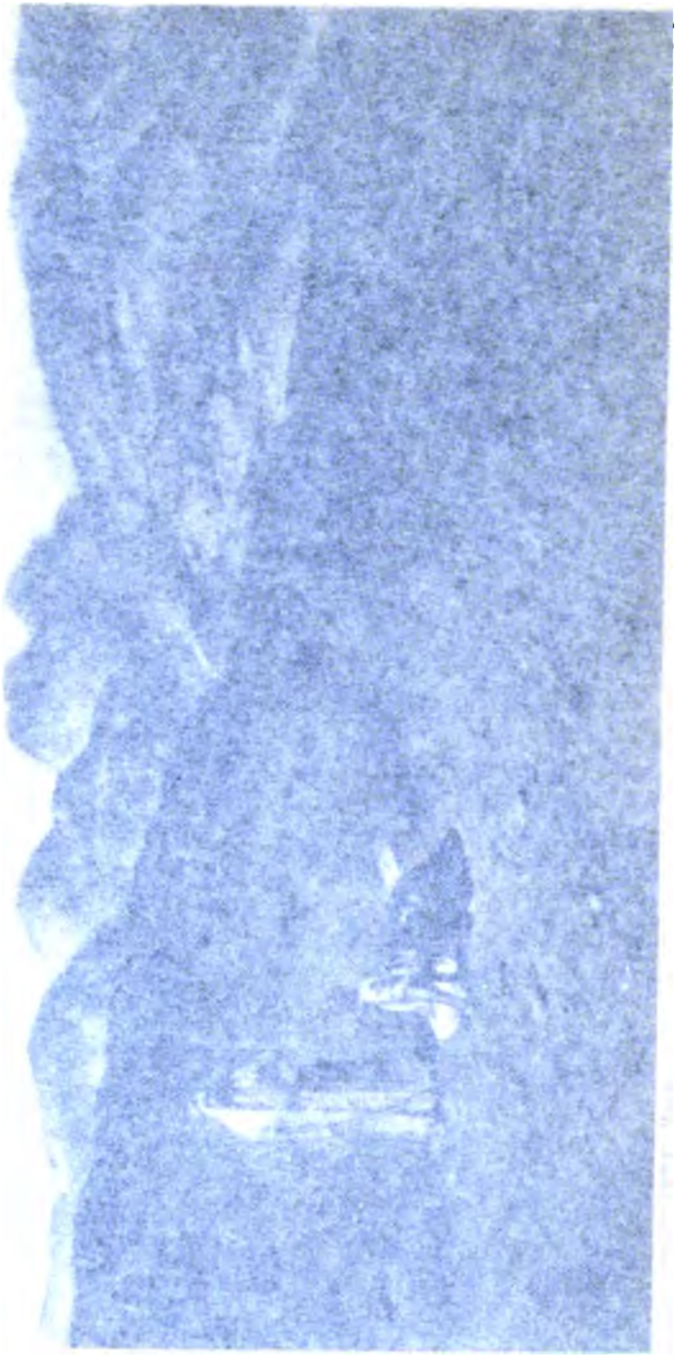
Photogravure by Dr. E. Albert & Co. Munich

JEBEL EL SHAYEB VIEWED FROM THE SOUTHERN SIDE.

GENERAL VIEW OF JEBEL JIDAMI FROM THE EAST.

[illegible] Wadi H[illegible] [illegible] and having [illegible] west [illegible] a long [illegible] water from [illegible] [illegible] [illegible] by the [illegible] the W[illegible] [illegible] district [illegible] Wadi [illegible] Markh[illegible] and the [illegible] to Wadi [illegible] W[illegible] would [illegible] Bas[illegible] [illegible]

Starting [illegible] its origin [illegible] Markh [illegible] country composed of a [illegible] mass of [illegible] [illegible] of dykes, [illegible] granite [illegible] Jidami,[illegible] [illegible] farther west, the same [illegible] plateau. The former [illegible] of Jebel [illegible] [illegible] country [illegible] north [illegible] the [illegible] tends [illegible] form [illegible] dykes which have a general trend [illegible] west. There is [illegible] doubt [illegible] the course of [illegible] by the granite [illegible] above mentioned, parallel to it, and for a part of its course at least, [illegible] between it and [illegible] of the [illegible] end [illegible] emanates from [illegible] receives [illegible] the [illegible] Qabin and Wadi [illegible] the north; [illegible] the granite range [illegible] and is a [illegible] tributary compared to the other, which is a [illegible] containing plenty of [illegible] in the form of aromatic plants, and [illegible] its origin in the wide stretch [illegible] between Wadis S[illegible], Um Tagher, Um Digal [illegible] its direction the valley would seem to come from



works similar to those in the Wadi Hammama, (see page 15) the hills all round having been mined and having had short horizontal shafts cut into them. At the south-west extremity near the El Nagateir plain, are ruins of stables (?) with a long cement-lined trough that appears to have been supplied with water from a now filled-up well, through earthenware pipes laid on a low stone wall. The pipes are of coarse-ribbed pottery and coned at each end.

II. *Wadi Abu Shia.*—To the south of El Hadrabia the country consists of an alternating series of sandy drainage lines and small hills—apparently dyke-ridges—extending up to the Jidami range, the uniformity being only broken by the somewhat higher and steeper crest of Jebel Abu Shia situated in the Wadi Abu Shia drainage system. The Wadi Abu Shia (name probably derived from "shia," *Artemisia judaica* aromatic plant) rises in this flat district between Wadi Fatiri and Wadi Markh, and drains into Wadi Markh, and so round the south side of the Abu Had range into Wadi Gareya, and finally W. Qena or Arras.

Jebel and Wadi Abu Shia.

From this point it would seem as if the main line of water-parting ran north towards Ras el Barud, from whence it passed on to Jebel el Shayeb.

III. *Wadi Markh.*—Starting from its origin in Jebel Markh the valley passes through country composed of a confused mass of black hills, probably owing their present shape to the presence of dykes. On its south side rises the granite range of Jebels Jarra, Jidami,* Missikat el Qukh, and further west the sandstone plateau. The former hills, beyond which is seen the peak of Jebel 'Aradia, form a massif of characteristically rounded crests which entirely shuts out the country to the south. On the north side the country tends to assume the form of parallel ridges, this being due to dykes which have a general trend north-east and south-west. There is little doubt that the course of this wadi has been determined by the granite range above-mentioned, as it runs practically parallel to it, and for a part of its course at least, forms the boundary line between it and the black rock of the surrounding district. About 10 kilometres from its head it receives from the south Wadi Missikat el Qukh, and Wadi Abu Shia enters the north; the former heads in the granite range bearing its name and is a comparatively unimportant tributary compared to the other, which is a fairly wide valley containing plenty of camel food in the form of "shia," a strongly aromatic plant, and takes its origin in the wide stretch of low country lying between Wadis Semna, Um Tagher, Um Digal and Fatiri. From its direction this valley would seem to come from near Ras Semna.

* See Photogravure No. 5.

As the western end of Jebel Missikat el Qukh is neared, Wadi Markh begins to widen out a little, and numerous bushes of "markh, shia, gurdi," etc., occupy its floor. On its southern side, the granite hills gradually slope down and disappear under the sandstone, differing in this respect from the vicinity of Wadi Jidami, where the hills rise up abruptly from the plain. On the north, too the black ridges become lower and lower until they also disappear under the sedimentary rocks. From this point the boundary of the latter sweeps round towards the Nagateir plain in a north-westerly direction.

In Jebel Missikat el Qukh, according to information supplied by the guides, water is found in various places in the water-courses which come down from these hills. None of these pools were visited as a plentiful supply had been obtained previously.

Sedimentary area.

On entering the sandstone area the wadi practically became a plain, there being no proper sides to it. As it was followed westward its bed became deeper, and low hills appeared forming almost vertical sides to it. The whole country was markedly different from that through which the Qena-Qosseir road passes, the rocks here never assuming the plateau-like character, but rather tending to break up into low ridges and isolated hills. As the junction with Wadi Gareya was approached the bold cliff of Jebel Abu Had was seen rising perpendicularly from the plain, and from its base a long tongue of secondary plateau was seen extending in a south-easterly direction. From its foot low ridges of sandy shales extended up to and beyond Wadi Markh, sweeping round behind the ridge of limestone and limestone conglomerate which lies on either side of its mouth, in the direction of Wadi Hammama. After leaving these sandy shales, the former winds through the hills of conglomerate mentioned, and joins Wadi Gareya a little above the ruined Deir.

Wadi Jidami.

IV. *Wadi Jidami.*—This wadi appears to have its origin in the conspicuous but isolated range which rises in the centre of the southern portion of the district, including the crests of Missikat el Qukh, Jarra, and Jidami. The latter is particulary noticeable from the peculiar rounded form of its four closely grouped summits, which are one of the most characteristic features in this part of the country, being visible from every elevated point for kilometres round. The precise starting-point of Wadi Jidami has not been fixed, though it probably commences at the foot of Jebel Jarra, soon dividing into two branches, one very smooth and even, passing round the northern end of Jebel Jidami, and after running between low ridges finally opening into the small Jidami plain, while the southern branch is entered from the plain by a gorge

RAVINE AT ENTRY OF JIDAMI RANGE

[illegible]

From Sheikh [illegible] [illegible] further into the [illegible] are old workings, which [illegible] exploited, but were lying [illegible] at the time of this visit. The veins [illegible] have been extensively worked, some still [illegible] hematite, though in the opinion of those who [illegible] the locality of late years, gold is considered to be present. The [illegible] of specimens obtained by the Survey parties have not yielded any evidence of the presence of the precious metal.

Near Bir Jidami and at the workings themselves are numerous [illegible] huts which might [illegible]; near them are lying a [illegible] number of crushing stones [illegible] with projecting handles. In addition there was [illegible] the lower stone on which the [illegible] was crushed. The [illegible] rubbing stones [illegible] a [illegible] chipped on the upper side. [illegible] water in the rocks after the winter showers, but it is in [illegible] quantities, so that when [illegible] had been filled and the [illegible] the supply was said to be exhausted.

In [illegible] plain of Jidami north of which rise a number of parallel, sharp, [illegible] At its southern end is a ruined [illegible] built of rough blocks of [illegible], which is rectangular [illegible] the longer axis [illegible] there is a doorway [illegible] western wall, the eastern one being [illegible] drift sand. No

about 100 metres wide with precipitous sides of igneous rock (see Photogravure No. 6). The floor of the wadi is here composed of coarse sand, while going up the southern branch towards its head, about 500 metres from the entrance to the defile, a road branches to the eastward, rejoining the main route at Bir Jidami, thereby avoiding a difficult point on the track. At this place is a narrow gorge, the road mounting by a slippery step of granite over 2 metres high, which laden camels are unable to ascend, and even unloaded they find it difficult. All along the defile diggings have been made for water, marks being placed on the rocks near them, but all these were dry at the time of this visit. The well known as Bir Jidami has been filled in by the Ababda during **Bir Jidami.** one of their feuds with the Maaza, but it might be cleared out without very much difficulty, as the Arabs report that there are only two or three large stones stopping it up, while four stunted palm-trees are growing in it at the present time. It is said to be a spring and not a rainwater- hole. Near by is the tomb of Sheikh Semarin, a rough stone hut with mats for a roof, the Arabs stating that he was a Wali of the Ababda tribe and a Hajji.

From Sheikh Semarin's tomb onward there is plenty of camel food and fuel, besides several large acacia (sellim). Still further into the hills are old workings, which are again being exploited, but were lying idle at the time of this visit. The veins in the hills around have been extensively worked, some still carrying hæmatite, though in the opinion of those who have examined the locality of late years, gold is considered to be present. The analyses of specimens obtained by the Survey parties have not yielded any evidence of the presence of the precious metal.

Near Bir Jidami and at the workings themselves are numerous miners' huts which might be Ancient Egyptian ; near them are lying a large number of crushing stones or grinders with projecting handles. In addition there was an example of the lower stone on which the mineral was crushed. These rubbing stones showed a grooved and smoothed surface on the under, and a rough chipping on the upper side. There is rain-water in the rocks after the winter showers, but it is in small quantities, so that when the tanks had been filled and the camels watered the supply was said to be exhausted.

In the plain of Jidami north of which rise a number of parallel, sharp, dyke hills, camel food and fuel are scarce. At its southern end is a ruined and half-buried building of rough blocks of granite, which is rectangular in shape, the longer axis being east and west, while there is a doorway in the western wall, the eastern one being buried in drift sand. No

fragments of pottery, except quite recent ones, were observed, these evidently belonging to an Arab encampment. To the west and south of the plain the sandstone is seen capping the igneous hills, forming deep brown or yellow-brown cones and flat summits, which after the plain and some low foot-hills have been crossed to the west, run together to form the sandstone plateau through which Wadi Jidami passes as a fine gorge, as described on p. 14.

V. *Wadi Hammama.*—One branch of Wadi Hammama takes its rise in a small plain through which runs the northern road to Qosseir, the drainage water flowing out in different directions at the east and west ends. North of this point the 'Aradia range forms the water-parting between the Nile and the Red Sea, and a change in the character of the country is at once noticeable, bushes and plants being much more abundant on the eastern side of the watershed.

Jebel 'Aradia itself is a large isolated mass of red granite, having a rounded appearance, and surrounded by sandy wadis, from which it rises steeply at first, but becomes less abrupt as the summit is approached.

In the granite hills around this central mass, rain-water is sometimes found in the crevices of the rock, but usually these fissures are dry, this being the case with one of the wells, Bir Moghabia.

Further to the east the valleys frequently widen into numerous small, sandy plains, as a rule enclosed by black igneous hills, having in their centre a much weathered mass of soft granite, whose disintegration appears to have given rise to the expanse. Close to these, a large valley runs in from the south, this being the true Wadi Hammama, which has not been further traced. Many of the "sellim" trees in this neighbourhood have been cut down for charcoal, the roots being dug up as well.

After the valley runs out of the granite region it winds about considerably among dark dolerite hills with steep sides, here being disused workings and miners' huts.

Further to the west the valley receives the tributary of Abu Jerida from the north, the latter winding in a tortuous manner among low dark hills, which are much veined, the dykes carrying hæmatite, while the latter mineral also crops out in more massive form near the western end, where old buildings and smelting places are common, these deposits having been largely worked in the past, probably by the Romans. At this point, yellow caps of sandstone are seen to rest on the dark hills, and after Wadi Hammama has received Wadi Um Sellimat, it soon enters the deep sandstone gorge previously described. See p. 15.

Wadi Um Sellimat, which takes its rise near Jidami, is chiefly interesting because it is bordered in one place by a cliff composed of a columnar rock.

After leaving the igneous hills, Wadi Hammama first runs between precipitous walls of sandstone, afterwards widening out as the sandy beds break up into isolated hills, and finally bending north to form the Hammama plain, its drainage passing through Wadi Gareya to Wadi Qena. T.B. and W.F.H.

3. *Eastern Side of Watershed South of Lat. 27° N.*—It has been seen that practically all the western drainage-lines, except Wadi Matula, etc., have one feature in common, viz., they drain into Wadi Qena, and thus the whole of this vast hydrographic system has but one opening into the Nile Valley, the one at Qena itself. The eastern side stands in sharp contrast, the numerous valleys descending from the hills running more or less parallel to one another, and each having a separate opening to the Red Sea. The two sides of the watershed south of lat. 27° N. are also very different; for while on the western side but few important igneous ranges are present, the eastern slopes are far more complicated, many abrupt and precipitous granite ranges rising suddenly from among the maze of low dark hills previously described, while in other places the tectonic changes described under the heading of "Geology" have given rise to most complex topographical features, the lithological variations having each corresponding scenic characteristics. Owing to this country having been examined by two independent parties, and the fact that but few of the valleys have been traced in their entirety, it will not be possible to deal with the wadis as a whole, but the routes followed will only to be described, the broader conclusions being reserved for a summary.

A. *Southern Qena-Qosseir Road.*—The main caravan road between Qena and Qosseir, after leaving the former place, runs along the edge of the cultivation until it reaches Bir Ambar. This is a small village **Bir Ambar.** so named because of the good wells of water which occur there. At the wells is a rest-house for pilgrims coming from Mecca via Qosseir. It is a handsome building built in the time of Ismail Pasha, capable of accommodating about 100 persons, and possesses several baths for the use of the people resting there. The only drawback to the place is the unprotected state of the wells, these being left exposed to the dust, and being consequently now in a rather filthy state. The place has evidently been neglected since this route has become less frequented.

The country to the east of the road from Qena to Bir Ambar is a low **Gravels etc.** plateau of gravel and marly clay much cut up by wadis, and sloping

gently upwards towards the limestone cliffs of Jebel Serrai. This plateau ends abruptly on the edge of the cultivation in a cliff varying from 18 to 23 metres high. Near its edge the valleys are wide, but as they are ascended they become narrower, and their sides higher and more precipitous, owing to the hard conglomerate forming them. The surface of this plateau is much dug over for salt and "sabakh"* near the cultivation.

After departing from Bir Ambar the road leaves the cultivation and strikes across the plain in a south-easterly direction towards Wadi el Qurn, up a branch of which it continues until it reaches Bir el Geita. After passing through the strip of country worked for salt, etc., the surface becomes covered with sand, being evidently much visited by sandstorms at different times of the year.

Wadi el Qurn. On entering Wadi el Qurn, which is a sandy-bottomed, wide, shallow water-course, the road bends round more to the north. On the south side of the wadi is a small plateau of shales and limestone, terminated to the west by a ridge of steeply tilted limestone called Jebel el Qurn, while its north side is formed of small steep-sided hills composed of igneous pebbles. Here the road left Wadi el Qurn turning more to the north in the direction of El Geita. At this point there is a confluence of three valleys; the main Wadi el Qurn which comes from the south-east and unites with Wadi Matula and Wadi Um Selat descending from the north-east, where the two latter head amongst the gravel hills.

Wadi Matula which comes from the low hills to the north of El Geita receives from the east Wadi Um Farag and further on Wadi Qareibat, both of which head amongst the low gravel and sand-hills to the east. It also receives Wadi el Geita and Wadi Rod'aid which rise in the sandstone to the north-east of the village of El Geita. In the winter there is plenty of camel food ("bsilla" and other plants) in Wadi Matula and Um Selat, but during the summer owing to the lack of water this withers up. In the former, the Tamarisk ("Etel," Arab) is plentiful. Jackals howled round the camp in Wadi Um Selat.

El Geita. The village consists of a number of mud huts, some in a ruinous condition, scattered in an irregular manner round the wells. It contains the ruins of what is probably an ancient Coptic church in fair preservation. It would seem as though this village was falling into decay, as the number of ruined houses is very large, and evidence of land having been under cultivation and now abandoned, is to be met with round about. The water supply is fairly abundant, and is drawn from thirty-four

* Sabakh is a marl containing a variable percentage of nitrates.

wells, four of which belong to the government and are kept in good repair by the Mudiria of Qena, while the others are simply holes in the ground. None of them are deep, and the water from them is brackish, but some yield sweeter water than others. On the west side of the village there is a pit from which water is lifted by shaduf to irrigate the patches of corn and cotton grown by the inhabitants. Near the Sheikh's house there is a larger garden than usual, in which cotton was growing when the village was visited. A few palm-trees stand near the wells, and there are also a few trees of the "sunt" tribe *(Acacia nilotica)* round the Sheikh's garden.

The people of the village belong to the Ababda tribe. They are very poor, and possess only a few camels, sheep and goats, which pick up what they can find on the plain around the village. The caravans passing to and from Qosseir nearly always stop here, and the people barter what they have for other things which they require. Several brace of sand-grouse "Qata" were seen here.

Cretaceous country.

The country round El Geita is a plain to the east, south, and west, in which a few small isolated hills of sandstone are present. To the north, the country is much broken, and gradually assumes the character of a plateau cut up by wadis, which falls away in a westerly direction eventually forming the foot-hills of Jebel Serrai, and disappears further south under the mounds of gravel which occur at the beginning of the Nile Valley plateau.

Wadi Rod'aid.

Passing eastwards the Qosseir road enters the Wadi Rod'aid, which runs into the Wadi el Geita. Before entering the valley itself, mounds of igneous pebbles were passed through on the edge of the plain. Here there was a large quantity of "bsilla" bushes which served as food for the camels from El Geita. No fuel was found here, but there were several trees of the "seyal" and "sellim" varieties and a striking feature is the remarkably rich green of the vegetation in this wadi as compared with the others, pointing to the possession of a underground water supply.

About 17 kilometres from El Geita, in a minor wadi to the south, there is a small pool of good water but only limited in quantity, from which the camel drivers fill their water-skins, but do not allow their camels to drink.

Qusur el Banat

Further up the valley are the ruins of what may have been a monastery called Qusur el Banat, opposite these being a curious undercut sandstone hill bearing the same name. On the eastern side of this hill are many rude drawings and some writing in Arabic, as well as the name Figari carved in the stone.

Wadi Um Sellimat.

At this point there is a change of name in the wadi, it now assumes that of Wadi Um Sellimat on account of the number of "sellim" trees in it. It is to be noted here that the fellahin who carry provisions to Qosseir call this wadi Matrah el Sellim.

Wadi Abu Queh.

Following up the waterway another change of name takes place the wadi receiving the name of Abu Queh after leaving the place where the sellim trees were abundant. This is a wider valley than those further to the east. From the north it receives a short, wide tributary called Hashma el Serrai, which seems to end only a short distance away. The former wadi receives all the drainage of the igneous and metamorphic ranges to the west of the watershed.

The country passed through after leaving El Geita is a typical sandstone one. It is a plateau sloping from east to west, having an undulating surface due to "rolls" in the rocks, and contains steep-sided wadis. Viewed from the west it presents a gentle slope of reddish-brown rock resting against the sharp peaks of the black hills of the metamorphic series and from the east a series of low scarped ridges sloping gradually towards the plain.

The main hill range.

The main hill range, composed as it is of metamorphic and igneous rocks, is topographically very complex. On entering it by the Wadi Hammamat the first hills are extremely steep and angular, and difficult of ascent, owing to the schistose and pebbly character of the rocks composing them. This style of country continues until the mouth of Wadi Atolla is reached, the hills closing in on the valley and forming almost sheer sides, while owing to the tilting of the beds at right angles to its course by the earth-movements which have taken place in this district, they do not lend themselves to an easy ascent.

From the top of one of the hills at the entrance to the main range the peak of Jebel Um Sharq, a well-marked conical hill, was seen over the top of the Hammamat ridge, while away to the north the plateau of Abu Had was also visible.

Hammamat Well.

In Wadi Hammamat there is a well which was constructed by English Engineers in 1830. It is properly lined with stone and mortar, having a parapet on the top to prevent animals falling into it. The water can either be drawn by means of a bucket attached to a rope and let down, or it is carried up in water-skins by means of a circular staircase which is constructed outside the pitching of the well. When it was visited there was not much water in it, probably about 2 metres in a hole in the clay at the bottom.

Behind the well is a square building which is probably of Roman times.

Further up the wadi are the well-known inscriptions and cartouches described by Lepsius and Golénischef. These are in excellent preservation.

The surrounding country continued very steep and hilly up to the entrance of Wadi Atolla from the north. At this point the Wadi Hammamat ceases and Wadi Foakhir begins, the direction also changing to the south-east. Here there were the ruins of a number of stone huts, probably inhabited by the miners who formerly worked in the vicinity. The ruins of a temple also occur at this point, the columns being made of the same stone as that on which the inscriptions, previously mentioned, were cut. On the east side of the valley is a boss of pink granite which has been quarried. There are several blocks roughed out and partly dressed and also a large vase which was probably used for the storing of corn. **Wadi Foakhir.**

Leaving this place and going in a south-easterly direction the Wadi Sidd was entered. At the entrance to the wadi the hills were still steep and high, but further on, owing to a change in the nature of the rocks, the region became more open, the sides being formed by low hills giving a plateau-like aspect to the district. Behind these on the western side of the valley rise the rugged hills of Jebel Hammamat, which form a boundary to the low country, sweeping round in a ridge and joining those round Bir el Sidd. At the point where the wadi bends round to the east, its sides again become steeper and continue so up to Bir el Sidd. This is a well which yields water at the level of the ground, of good quality and fairly abundant. It is not at all deep and is surrounded by a well-built wall of stone and lime. Near by are a few Arab tents, and there are also a few caves (maghara) which are used by the people as dwellings. **Wadi Sidd.** **Birr el Sidd.**

Immediately behind the well is a pass which is a little difficult for laden camels. This is due to the presence of a very tough resistant rock in the bed of the wadi.

From the top of a hill overlooking Bir el Sidd a good view of the surrounding country was obtained. To the north-east in the direction of Wadi Atolla the district was composed of low hills which stretched away to the north and eastwards as far as the watershed at the head of Wadi Rieh, to the south the conditions being similar.

In Wadis Hammamat and El Sidd camel food was fairly abundant, but there was no fuel.

After crossing the pass behind Bir el Sidd the ruins of seven houses were reached; near these was a Sheikh's tomb, around which was a burial ground. From this point the valley becomes wider and is bounded

by low hills, while a little further on two wadis, both bearing the name of Dub el Beida, enter from the north and south. These drain the confused mass of low hills, which being composed of schists, lends itself easily to the formation of ridges roughly parallel to each other.

From the point where Wadi Dub el Beida joins the main waterway, a change of name again takes place, the valley being now called Wadi Rieh.

Wadi Rieh.

This receives from the north the Wadi Maghara, after which it rises rapidly to the watershed where a few higher hills appear along the parting-line; from this point the road goes over a steep and narrow pass which is rather difficult, and descends rapidly to a small open space on which was a Bedawin encampment.

This pass is the parting of the water which flows respectively into the Mediterranean and the Red Sea.

From a hill overlooking the Bedawin encampment a general view of the country was obtained. To the south rises a ridge of sharp angular gneiss summits, of which Jebel Um Sharq* forms the highest peak, bounding the lower hills in the immediate neighbourhood of the valley. This range bends away further to the south, but later on seems to sweep round and join the hills which form the massif round Bir Seyala. On the northern side the ridges of schist run up to the foot of a high pink range which bounds the country to the north, and runs in a south-easterly direction until it nears Wadi Um 'Arada, after which it bends round and runs east parallel to this wadi, eventually forming the sides of Wadi Seyala. This ridge is very steep-sided and similar to that on the south side.

Wadis Rieh, Abu Zeran, and Um'Arada.

Between the two ranges on either side of Wadi Rieh, the hills are first of all rounded, being granite, and later on much more angular as this rock shades off into gneiss and schist. This continues until Wadi Rieh enters Wadi Abu Zeran, when a change comes over the country. It becomes more open and approaches a plain in character, small rounded mounds of granite and metamorphic rocks being scattered about over it. The drainage from this plain goes into the Wadis Abu Zeran and Um 'Arada. As Wadi Um 'Arada was approached the hills closed up on both sides until they joined the massif in the neighbourhood of Bir Seyala.

In Wadi Rieh there occur the ruins of what may have been a caravanserai at one time. It is called "Lokala" by the guides, the name of the wadi in which it occurs being always attached to it. Another of these ruins occurs in Wadi Um 'Arada, called Lokala Um 'Arada. Near the latter place a road branches off to the north,

*See Photogravure No. 7.

Photogravure by Dr. E. Albert & Co. Munich.

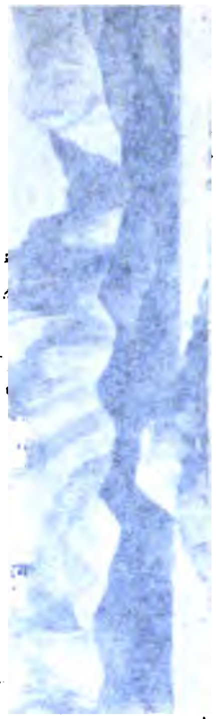
JEBEL UM SHARQ SEEN FROM THE NORTH

[illegible]

[illegible] Northern Qena [illegible] Route [illegible] there [illegible] that touching [illegible] and running [illegible] for Assuan and [illegible] usually followed. [illegible] considerably [illegible] through the desert, passing [illegible] to the old [illegible] and joining the first named near Bir Seyala. [illegible] further [illegible] watershed at Wadi [illegible] Semna and so through Wadi Saga to Qosseir, [illegible] by Dr. Schweinfurth in [illegible] 1885, and which, [illegible] the [illegible] of the district is [illegible], will help to fill up the unexplored [illegible] between Jebel [illegible] and Semna.

Northern route by [illegible]—Leaving Qena, the camel track after passing up the [illegible] wadis of Qena and Um Selliheat, crosses the pass at the head of the latter valley, and descends through steep gullies to the plain of [illegible], which gradually narrows until the sandstone gorge of Wadi Hammama is entered. On leaving the sandstone a little west of the watershed, one of the most characteristic features of the scenery is the abundance of deep red quartz felsite veins running through the black diorite rocks and apparently converging towards the Jebel [illegible] range, which rises to the north. Wadi Abu Jerida itself runs through these dark hills, the veins in which have been extensively worked for the hematite they contain, their sides being seamed with fissures and cavities still in places lined with fragments of sparkling micaceous ore. On the

Hematite at W. Abu [illegible]



and according to our guides it leads to Bir Um Disi. This road passes through the high range of gneiss previously mentioned, in which water is also to be found.

Camel food is plentiful in these wadis, the main plant being "bsilla," although there was some coarse grass here and there.

Near the head of Wadi Rieh, several brace of sand-grouse passed over in the morning.

In a wadi draining into Wadi Um 'Arada, three gazelle were seen.

Following Wadi Um 'Arada the road enters Wadi Seyala, so named because of the number of the trees of that name which grow in it, and in a bend at the junction of a side valley with the main one, Bir Seyala is situated. This well is of the same pattern as that of Hammamat, having steps down to it. At the time it was visited it was undergoing repairs at the hands of some workmen from Qena. The water is fairly abundant, and slightly brackish in taste. Near the well are a few Arab huts, the owners of which seem to be in extreme poverty. T.B.

B. *Northern Qosseir Road.*—There appear to be three main roads to Qosseir, that touching the extreme south of the area, and running through Bir Ambar and El Geita, being the one usually followed. A second one runs considerably to the north through the desert, passing close to the old hæmatite mines of Abu Jerida, and joining the first named near Bir Seyala. A third runs still further north, descending from the watershed at Wadi Jidami to Wadi Semna and so through Wadi Saga to Qosseir, a road which was examined by Dr. Schweinfurth in 1884-85, and which, when the map he has made of this district is published, will help to fill up the unexplored gap between Jidami and Semna.

Northern route by Abu Jerida and Meeteq.—Leaving Qena, the camel track after passing up the wide and barren wadis of Qena and Um Sellimat, crosses the pass at the head of the latter valley, and descends through steep gullies to the plain of Hammama, which gradually narrows until the sandstone gorge of Wadi Hammama is entered. On leaving the sandstone a little west of the watershed, one of the most characteristic features of the scenery is the abundance of deep red quartz-felsite veins running through the black dolerite rocks and apparently converging towards the Jidami range, which rises to the north. Wadi Abu Jerida itself runs through these dark hills, the veins in which have been extensively worked for the hæmatite they contain, their sides being seamed with fissures and cavities still in places lined with fragments of sparkling micaceous ore. On the

Hæmatite in W. Abu Jerida.

northern side of the valley, too, conspicuous bands of jasper make their appearance, while to the west and south caps or knobs of sandstone over 100 metres high rise abruptly from the dolerite, having perfectly smooth summits covered with broken masses of slaggy-looking ferruginous sandstone. In the wadi single trees of "sellim" (*Acacia Ehrenbergiana*) occur at irregular intervals, and on crossing some low hills a change both in topography and geology is noted. The dark green conical hills open out right and left, the valley widening between them, and containing low light-coloured ridges having the characteristic rounded boulder-structure familiar in granite areas, while to the north rise the conspicuous summits of Jarra and Jidami. Soon after leaving this opening, the valley becomes the boundary between two distinct types of country, the northern slope rapidly rising and being composed of granitic hills, over 200 metres above the valley, having abrupt smooth slopes, and characteristic rounded summits, upon which huge rounded blocks of weathered granite are perched. The watershed is formed by a small plain at this spot, the slope then rapidly descending towards the east, and the valley now being known as Wadi 'Esh. At one spot water was present in one of the fissures in the granite, it being beautifully clear and pure, and in such a position that the ibex, etc., cannot get to it easily. From this point the road runs through a long plain, 7·5 kilometres wide, evidently owing its origin to differential denudation of the granite and the dolerite, having black igneous hills on both sides and rounded masses or weathered granite down its axis. At its western end, up a small wadi which rises at the foot of J. 'Aradia, are the remains of miners' huts with broken pottery and fragments of rubbing or grinding stones, and in places numerous stone circles are also present. At the eastern end of the plain *Dœmia tomentosa*, an Asclepiad with heart-shaped leaves and milky sap, was first met with in abundance, though it is one of the commoner plants in the Red Sea Hills. Here too is the exit of an important south-running branch, Wadi Atola, which has cut through the compact doleritic rocks, rising steeply (probably about 70 metres high) on both sides. About 4 kilometres to the south the valley receives a tributary from the north, close to their junction being a dry water-hole which is full after rain, the Arabs watering their flocks of goats at this place. On the dolerite near this well are inscriptions, apparently of two periods, the later one representing a king (Rameses III) making an offering to the god Amen-Ra. There are two cartouches in excellent preservation above the king's head, the whole inscription being about 0·3 metres square, while there are no other inscriptions on the stela

Wadi 'Esh.

Rameses III Inscription.

RAMESES III. CARTOUCHE ON DOLERITE ROCK IN WADI ATOLLA.

See p. 52.

MICA-SCHISTS ON SUMMIT OF JEBEL MEETEQ.

See p. 52.


Photogravure by Dr E Albert & Co Munich

GNEISS HILL IN MEETEQ RANGE.

After passing ... to the north-east of ... west, but falling steeply to the east, ... and south. The main ... precipice of 600 metres, and the ... line, the sharp serrated ... crests, while the crests of the ranges are ... peaks and points, such as are characteristic of ...

except the two cartouches. There is another cartouche roughly hammered on the same slab of rocks. Many miners' huts, rubbers' pestles, etc., are in the valley near to this inscription, and in many places the downwash in the drainage lines and at the mouths of small "khors" is covered with numerous shallow pits, but there was no indication as to the object of search.

This locality having been especially visited to examine the cartouche (the camels going down the main Wadi 'Esh) the return journey to camp lay over rolling country of purple and grey schists, dipping steeply south-west.

In Wadi Atolla a tree was noted, the "ushr,"* carrying a big pod-like fruit, and having large smooth shining leaves. This is the only occurrence met with in the Eastern Desert, but in Eastern Sinai, especially in Wadi Gnai, near the gulf of Aqaba, it is not uncommon and very abundant near the Nile in Nubia.

El Rebshi range.

The country at this point is very varied in its structure, the bouldery granite being conspicuous in the wadi itself, while to the south extend the wedge-shaped dark hills of dolerite as far as the eye could see. To the east a sharp high ridge rises over 400 metres above the general level, this being the El Rebshi range, a rectangular mass of hills of a reddish colour, broken up into several well defined peaks. Its sides are steep and covered with loose fragments, while the mountain mass is much cut up by steep-sided water-courses, separated in places by narrow ridges and saddles, which render the ascent somewhat difficult. In the low country, at its foot, camel-food is scanty, but sufficient for a small party. A very prominent quartz-ridge was used as a station, but in general the undulating country at the foot of El Rebshi consists of slate which forms low hills having a peculiarly glittering surface, intersected by numerous drainage lines converging to a point, where, after cutting through a range of low dark hills, they turn sharply to the east, and flow in the direction of the Red Sea.

Jebel Meeteq.

After passing El Rebshi, the road, a well-marked single track, runs to the north-east of Jebel Meeteq,† a dark massive hill rounded to the west, but falling steeply to the east, while sharp spurs project both north and south. The main summit rises from the valley in an almost sheer precipice of 600 metres, and the whole of this gneissose range is very fine, the sharp serrated aiguilles being separated by deep precipitous gorges, while the crests of the ridges are broken up into thin jagged combs and points, such as are characteristic of schistose districts in the

* *Solamun sanctum.*

† See Photogravure No. 8.

Swiss mountains and elsewhere. There is plenty of water in the pools on the sides of Meeteq, and according to the reports of the Arabs it is never exhausted. Jebel Meeteq itself is easily ascended from the western side up the steep slopes of shining slates which compose it, and observations with two aneroids and hypsometer give its height above sea-level as about 1100 metres.

Although comparatively low, in its infinite variety of form and precipitous outlines the range of Meeteq presents a picture of gloomy grandeur which is only exceeded in the Red Sea Hills by the deep ravines of the Central Range and the towering crests of El Shayeb and Gharib. To the north extends a region of low dark hills, where not a single prominent summit breaks the monotony of the outlines, yet which is so cut up by winding valleys that a large scale map would be necessary to show all the detail. As it is, on the present map it has been found impossible to attempt the delineation of this type of scenery in the time at disposal, it must suffice here to state that all the drainages of this lower country appear to enter one valley-system, that of El Sodmein, which, commencing close to the base of Meeteq, runs among the gneissose hills for some distance, till it suddenly turns west after a fine ravine has been traversed. From this point it passes through the dark hill-country until it reaches the limestone range of Duwi, standing at right angles to its course which, however, offers no impediment, a fine gorge cleft from top to bottom giving it passage, after which its further course has not been studied till it approaches the Red Sea.

The road to Qosseir leaves the valley and, crossing rather higher and broken ground, descends Wadi Edid till it joins the main road in Wadi Seyala near Bir Seyala. While, as has been said, the gneissose hills themselves present many features of beauty, and are succeeded to the north by a secondary range, also schistose, which presents bold outlines, the darker hills through which the Edid portion of the road runs, have a decidedly depressing effect, the monotony being unrelieved by vegetation or variety of colour exept the deep red of the felsites veining them.

The contrast on issuing into the main road is very great, and instead of the silence which seems to brood over the district just traversed, the Seyala valley appears to be the scene of constant movement and bustle, as flocks of sheep, herds of camels, and Arabs and donkeys pass on their way to or from Qosseir.

Soon after the junction with Wadi Seyala the road runs out into a plain, which is seen to be closely connected with a topographical and

TRAVERSING A RAVINE IN THE GNEISSOSE RANGE OF MEETEQ.

See p. 54.

GORGE IN GRANITE RANGE OF JEBEL AGHARRIB.

See p. 59.

geological change of a very marked nature, for although bounded on the west by low black hills, on the east rises a long range of limestone, facing the plain with a wall-like escarpment, Jebel Duwi or Um Hammad. In the plain itself is a line of small isolated knolls of Nubian Sandstone on which are rude drawings of camels and ibex, and on one of them, close to the road, two or three much defaced Cufic inscriptions. The track, after crossing the plain, passes through a sharp S-shaped bend and thus continues its eastward course between dark igneous hills until the ruined khan of El Hamra is reached, where cliffs of Nubian Sandstone form the eastern side. The building is in ruins and seems to have been more or less a stronghold as well as Khan, in the centre being an excavation about eight feet deep; but now dry. The stone door-posts are *in situ*, though one has fallen on to the other; on the western one are Arabic inscriptions and a roughly hammered and much weathered Sinaitic (?) inscription.

The valley, which is here known as Abu Zeran, has its direction evidently determined by the junction line of the sandstone and igneous rocks, the former rising in cliffs to the north, while the latter occur as black jagged hills on the south. On the Nubian Sandstone are tribal marks, some of these belonging to tribes from the Hajjaz. Finally, Wadi Zeran turns obliquely towards the limestone cliffs of Duwi, through which it passes by a large gap near a well known as the Bir el Inglizi or Bir el Beida, where a few Arab hovels are met with. Vegetation and fuel were abundant throughout the valley.

Jebel Duwi itself entirely owes its origin to faulting on a gigantic scale, by which the Tertiary and Cretaceous limestones and Nubian Sandstone have been tilted into their present positions, the range consisting of a long sharp ridge which drops precipitously to the south-west and slopes in a steep angle, generally over eight degrees, to the north-east, the individual beds appearing on the surface like the contours of a map. Nor is this faulting limited to this particular line of hills. Other crests similar in character are seen both to the south-east and north, in such cases the limestones and sandstones reappearing in the same succession, and being sharply cut off by the dark hills which surround them. It is not necessary here to classify all these occurrences, many of which are mentioned in the geological part.

After passing through the gap, the road runs across a sandy plain and enters a wadi in which is a spring of brackish water, Bir Ambagé, near which are some Arab hovels. From this spring the water flows in a small stream, which gives rise to a marshy strip about half a kilometre long and 50 metres wide. The stream itself runs for about

half a kilometre, and is then absorbed by the gravelly bed of the valley, while in its course it appears to be depositing travertine.

Shortly after Bir Ambagé is left, the valley opens out towards the sea, having low limestone cliffs on both sides, which soon make way for a gently undulating slope of gravel forming the slight rise on which the upper part of Qosseir is built. The latter is not a very interesting town, consisting of broken-down looking houses, though near the shore itself stands the more imposing building of the Custom-house, etc., and the chimney of the condensing station also forms a prominent object. A little to the south of the town is a small palm-grove, but this is practically the only sign of vegetation in what is otherwise a barren waste, on the south bounded by gravel terraces, behind which rise flat plateaux of gypsum and a range of dark green dolerite, etc., on whose sides rest grey uplifted coral reefs. The charm of Qosseir lies, not in its ancient fort standing conspicuous but useless on a raised mound, or in its hot dusty gravel plain, where wind and flies unite to make life unpleasant, but in the deep blue colouring of the sea and the ever varying pictures presented by the coral reef and its inhabitants, which have been so well described by Dr. Klunzinger*.

W. F. H. & T. B.

C. *Road from Qosseir up Wadi Semna to Mons Claudianns.*— This road follows the main track to Qena, till at a point about 2 kilometres east of Bir Ambagé; it leaves the valley, and crossing a low watershed enters a new drainage system which has its outfall at Old Qosseir. A path from Bir Beida runs down this drainage line to that site, but does not appear to be much used. The topography of the country at this point is difficult to describe, hills of varied character but no great size rising in various directions. The most uniform of these is a low, dark, igneous ridge to the south, which runs parallel to the road for some distance, while in front rises a bold limestone hill, here named Jebel Nakheil in the absence of a local name. At the eastern foot of this elevation is a broad plain dotted over with greenish-coloured hillocks, the remains of green shales, while Jebel Nakheil itself consists of two superimposed plateaux, due respectively to Cretaceous and Tertiary limestones. From the plain, however, the tracks turn sharply south-west across the igneous range, here becoming for a short distance a steep, stony path practicable, but difficult, for laden camels. The descent into Wadi Nakheil is easy, the valley extending as a long flat expanse for a breadth of three kilometres,

*Oberägypten Chap. VI.

until the slopes of Jebel Duwi, with their curious contourings, rise suddenly from the plain. Indeed, the dip-slope and escarpment of the Duwi range is the most marked feature in this district, the former to the north-east being of variable angle, beginning almost as a horizontal plateau and gradually increasing in steepness till the plain near Bir Ambagé is reached, while the angle may be as much as twenty degrees, the whole slope being cut up by V-shaped watercourses. Wadi Nakheil forms a small plain near its junction with the valley of Bir Ambagé, at the northern end of which is the well of Bir Nakheil, containing brackish, though drinkable water, but owing to neglect the pools are now filled with vegetation. Around the well are a few stunted palms from which it takes its name, and about 10 metres to the west are the ruins of a "lokala" with a dry excavation in the centre. On the opposite side of the valley at the foot of the hills are ruins of a village of rough stone huts, square in shape, having from two to three rooms each. The limestone cliff close to this point is a striking object, owing to the steep angle (forty degrees) of the bands of flint which run through it, while to the north-east the slopes of Jebel Nakheil are bounded by deep brown hills of sandstone, which also form very conspicuous objects in the landscape.

Already from near Qosseir a big hill can be seen rising above the low country, the granitic range of Hamrawein, which, as Bir Nakheil is left, rises boldly in front, a small track winding round its south-eastern edge among low dark hills leading into the Hamrawein or Abu Hamra drainage-system. Though moderately steep, the ascent of the mountain, which rises 400 metres above the valley, presents no special difficulty, the top being a long, flat, but narrow, undulating plateau. The view from the summit impresses on the mind the diversified character of the country produced by the faulting, for immediately opposite on the south-west side, and only separated by a comparatively narrow valley, rise the steep slopes of Jebel Duwi; to the north-west the granitic crest lowers rapidly till it is bounded by low conical dark green hills, against which rest small hummocks of white limestone, indicating the line of fault; while to the north-east spreads the same low country, cut up by numerous tortuous and tributary wadis into black ridges rising about 15 to 30 metres above valley-level. Among these valleys are one or two, which seem to have followed lines of dykes, for they run in a perfectly straight line for a great distance; the largest is that forming the road from the foot of Hamrawein to the Wadi Sodmein, while there is a smaller example running in a north-west-south-east direction north of Jebel Hamrawein.

Wadi Sodmein. The track to Wadi Sodmein is a small one, but well-marked. As has already been stated this valley rises at the foot of Meeteq and receives all the drainage of the country in that neighbourhood, after which, running east, it cuts through the Duwi range at about two-thirds of its length from the gap at Bir el Inglizi to its end in Wadi Saga, and outfalls at Bir Queh north of Old Qosseir. A road from Meeteq runs down the Wadi Sodmein to join the Qosseir-Suez road; another branches from it at the point where it breaches the escarpment of the Duwi range, running up Wadi Kob-Ayeb into Wadi Nakheil and so to Qosseir, also forming a well-marked track.

At the point where W. Sodmein is crossed, vegetation is very abundant, there being a small grove of graceful "atl" (tamarisk). After crossing Wadi Sodmein, the road ascends Wadi Saga, a large tributary coming in from the north. A second grove occurs about 3 kilometres up the valley and this association of trees together at these two localities is a striking feature, because usually in the desert they occur at intervals and widely apart. Wadi Saga rapidly narrows to a ravine bounded on both sides by absolutely vertical walls of limestone, cut through in places by small water-courses running from the upper or main cliffs of the range. Indeed one of the noticeable features at the northern end of the Duwi range is the fact that it consists of two plateaux, the southern rising steeply above the other, through which the Saga gorge has been deeply cut.

This fine gorge is filled with bushes, and its sides are much undercut by the streams which must rush through here after the winter rains, carrying all before them, though from the abundance of the tamarisks such torrents cannot be of frequent occurrence. To the north, owing to geological changes, the ravine and limestone range cease simultaneously, the road suddenly entering the Saga plain, which contains two low ridges bending round in a long curve and a number of isolated brown-red hillocks of Nubian Sandstone. The plain is bounded on the west by a straight line of low dark hills forming the under features of Jebel Hamir, a large dark mass with a well-marked point, and on the east by the foot-hills of the granite range of Rushud, in which are a few small pools of rain-water, while rain-water of good quality and quantity is found in the pools that occur in the gullies at the base of Hamir. As fuel and camel-food are also abundant this district is very favourable for camping purposes.

Wadi Saga itself comes through the low black hills in a very tortuous manner, the going for camels being excellent, as the tracks are very smooth. A curious feature here is the abrupt way in which steep

granite crests rise from among the lower hills. One of the most conspicuous of these, Jebel Agharrib, was ascended, it consisting of a series of rounded and smoothed slopes, gradually rising towards the summit, and separated from each other by steep ravines, which toward the base become precipitous gullies containing numerous water-pools.

Wadi Waera appears to drain in two directions, one part going to Wadi Saga direct, while a low watershed having been crossed, another leads into Wadi Semna. Mapping in this low hill district is not easy, distances being determined by wheeling along the comparatively smooth valleys, which are enclosed between apparently unending low ridges up to 100 metres high and of monotonous dirty green-colour. When these are ascended the view extends over kilometre after kilometre of the same dark, wedged hills, out of which granite crests rise abruptly, while in the distance other isolated ranges stand out against the sky-line. Wadi Semna itself sweeps down from the north as a fine broad valley, a little above the junction of Wadi Waera containing ruins of a large "lokala" standing at the entry to a small khor, up which are numerous huts and a small temple containing a Greek inscription of twenty-two lines, of which Green took a squeeze and made copies. This inscription, which was apparently previously unknown, is of Roman date; in the fine diorite or gabbro at this locality, there are two or three quarries in the hills above the temple, while a road, about 1½ metres wide, leads down one of the small khors in the direction of Wadi Semna. This wadi is well supplied with camel food and fuel, and in reality consists of a number of branches draining an extensive region of low hills, which are all highly magnetic, markedly affecting the compass. It is also remarkable as being the only one of any length which has a distinct trend from north to south, though the reason for its presence and character is not easily traceable. Following up the valley the traveller eventually enters a sandy plain, flanked on the east by the dark range of Abu Marwat (pronounced by the natives Abumrewat). These hills, though steep, have rounded surface outlines, but one somewhat conical peak at once strikes the observer from having the beds near its summit thrown into a series of remarkable V-shaped curves, which closer examination has shown to consist of siliceous ironstone, in places associated with hæmatite. **Wadi Waera.**

Two rather prominent, low, yellow hills north of the Abu Marwat plain mark an important change both in the scenery and geology, the low hills rapidly passing from the ridged types produced by the dolerite and ashes, to the bouldery granite scenery, the whole country consisting of low knobs, or tors, separated by meandering sandy drainage lines,

the general slope of the whole being north-east, and all converging to form the important valley of Safaja. There is a considerable quantity of blown sand in this district formed by the decomposition of the granite knolls. This sand is piled up against the lower slopes of the larger hill masses, notably Abu Farad, and a long ridge to the north of it, forming a white fringe round their bases that may be seen from a great distance.

After entering the granite country the road cuts across a number of low ridges separating tributaries of Wadi Safaja, until a wide sandy plain sloping gently from the bases of the granite hills of Barud and other large hill-masses, and draining south, is entered. This plain is dotted over with small knolls formed by dykes that run east and west, or south-east and north-west, but which afford practically no shelter from the bitter wind which sweeps across the expanse in winter.

The country to the west is a low plateau cut up by numerous wide, sandy, drainage lines into a series of wedges that extend westward as far as the plain of El Nagateir, being bounded on the north by the mountain ranges of which El Shayeb is the chief peak, and on the south by the Hamir and Markh ranges. The watershed is situated approximately on a line joining the Markh range to Ras el Barud, but the western end of this line was not examined, and may have to be placed more to the east.

No feature of topographical interest lies between the sandy plain and the rocky gully which leads over the watershed to the westward-draining system of Wadi Fatiri. W.F.H.

D. *Road from Qosseir via Wadi Safaja to Qena.*—Leaving the valley of Nakheil by the path previously mentioned as crossing into Wadi Hamrawein, Jebel Hamrawein was ascended, and from its summit a good view of the main ranges and peaks of the hills was obtained. To the south rose the rugged crests of Jebel Endusi, while to the west the sugar-loaf hill of Jebel Um Sharq, and the rounded summit of Jebel Meeteq were prominent, and on the north, Jebel el Shayeb, Jebel Barud, Jebel Um Kabbash and Jebel Nugara are conspicuous. From the foot of this hill stretches eastward a very complex mass of low, black, schistose hills which gradually become lower and disappear under the Nubian Sandstone to the south, while they extend north as far as can be seen, abutting on the flank of a red granite range which is one of the striking features of the country. The Wadi Hamrawein at this point runs through a syncline in which lies Nubian Sandstone; the edge of the basin is seen to the south, forming a flat-topped ridge which is evidently continuous with another on the north side of Wadi Nakhheil,

The sandstone on the southern side of the wadi lies on the flank of the granite range, eventually rising up and covering it. This ridge consists of a series of sharp peaks, many of them inaccessible on account of their rugged nature. The wadi breaches this range by a narrow gorge with sheer, precipitous sides, on the eastern side again entering sandstone country through which it winds, and after passing through a ridge of black diabasic rocks crosses the coast-plain to the sea.

Wadi Hamrawein. This wadi heads in Jebel Hamrawein, of which it drains the eastern side, and passing in a tortuous course through the black schistose hills, and the granite ridge above-mentioned, falls into the sea about 14 kilometres from its source.

Coast Plain. The ground on the eastern side of the igneous range forms a sloping plateau varying in height from 188 metres on the landward side to 18 metres on the sea-shore. In width it likewise varies considerably; at its widest at Wadi Queh it is 12 kilometres, and narrows down to 2 kilometres in the neighbourhood of Old Qosseir. To the south of Wadi Hamrawein a broad area of buff-coloured rounded hills with narrow steep-sided water-courses is present on the flanks of the black igneous range; while close by the place where the wadi leaves the hills small knolls of limestone rise on either side of it. Seawards the ground is covered with various kinds of pebbles, and the sides of the wadi are formed of a conglomerate of these rocks. About a kilometre from the shore a narrow ridge of limestone rises above the general level, and is continued by isolated hills parallel to the coast for about 16 kilometres where it dies out, reappearing again after about 7 kilometres, and running up to Wadi Safaja, a distance of 35 kilometres or thereabout, its greatest height being 110 metres. North of Wadi Queh, three areas of the buff-coloured rock previously mentioned rise out of the plain; while further north as far as Wadi Safaja these hills occupy the flanks of the igneous range, until in the neighbourhood of Wadi Salem, sandstone is interposed. These rocks form a pleasing contrast with the pink granite at the back, and the dark-green foot-hills, the red sandstone, the white limestone, and the deep blue of the sea in the foreground, especially when viewed in the afternoon, with the slanting rays of the sun casting various soft tints over all, and blending them into one harmonious picture.

Camel food, water, etc. Taken as a whole this plain is rather of a barren character, camel food being not at all plentiful in the valleys except in Wadis Sodmein and Safaja; while water is only obtainable at Safaja, where it is brackish. After rain however, it is also found in a hole in Wadi Queh, but it soon becomes brackish and dries up.

At certain places along the coast there are lagoons round which numerous bushes of a species of tree resembling a water-willow* grow.

At the mouth of Wadi Queh are a few huts belonging to Arab fishermen, who are in extreme poverty, living almost entirely on fish, with a little coarse bread at rare intervals.

The ruins of the old village of Jasus occur at the mouth of the wadi of that name, all that now marks its position being a few tombs and a dilapidated house. In the plain about half a kilometre to the north of Wadi Safaja there is a well of brackish water that only camels and men who are accustomed to it can drink. According to the guides this well very rarely fails.

Between Wadis Hamrawein and Safaja the following valleys drain into the sea:—

Wadis in the Coast Plain.

Beginning from the south, the first of these is Wadi Abu Hamra, which was pointed out by the guides as heading in the northern spur of Jebel Hamrawein. From this point its course could not be determined until it was seen in the coast-plain.

Wadi Sodmein was also pointed out from the above-mentioned hill, meandering among the low black hills which lie to the west of the red granite range, and after breaching the latter making its way through the beach-plain into the sea.

Wadi Queh, of which there are two drainage lines, heads in Jebel Queh or Saga, the red granite range which runs parallel with the shore, from whence it carries the water through low-sided water-courses to the Red Sea.

Wadi Salem likewise consists of two short drainages which meet close to the sea-shore, and receive the water from Jebel Abu Shigeli. To the north of this valley is Wadi Abu Shigeli, which also heads in the range of that name.

Finally, Wadi Jasus drains the area of Jebel Abu Diab and Jasus, and likewise the low hills of sandstone and gypsum which form the plain at these points.

Igneous country bordering the Beach.

As was stated previously, the outstanding feature of the country in this district is the red granite ridge which runs more or less parallel with the shore. This begins about 7 kilometres south-east of the point where it is breached by Wadi Hamrawein, and after running an equal distance in a north-westerly direction bends sharply round in an almost due north line. The remarkable feature of this range is the number of sharp jagged peaks it shows all along its crest, bounded in many

* The "shora." (*Avicennia officinalis.* L.).

cases by almost sheer precipices which are rendered inaccessible on account of the rotten nature of the rock. At its southern end it is flanked on both sides by Nubian Sandstone which further on gives place to the black schistose rocks forming foot-hills and making such a pleasant contrast with the dark red of the high peaks. The schistose rocks which lie on the flank of this granite ridge stop abruptly against the sedimentary series of the plain, in some places, as at Wadi Hamrawein, having limestone laid against them, while further north gypsum, and lastly sandstone are successively found abutting on them.

Jebel Saga. The red range from the point where it bends round to the north bears the name of Jebel Saga, which persists for the whole length of the ridge to its northernmost limit.

Jebel Abu Shigeli. Fourteen and a half kilometres from the bend in the hills the ridge bifurcates, the eastermost limb retaining the true north bearing, while the other (Jebel Saga) bears north-north-west, taking the name of Jebel Abu Shigeli. After running for about 7 kilometres in this direction, this range turns sharply north-west for about 5 kilometres, when it again assumes a more northerly bearing, veering round to north-north-east, eventually returning to the north-west line and ending in Jebel Safaja or Abu Diab.

Although this range preserves the same name throughout, it ought according to the rule amongst the Bedawin (viz., that a hill mass takes the name of the main wadi which drains it) to have two other names, *i.e.*, Salem and Jasus, as wadis bearing those names receive the water from it.

Between the two wadis of Abu Shigeli a small granite ridge, with axis bearing east-north-east and west-south-west, breaks through the black foot-hills and occupies the edge of the sedimentary area.

Jebel Abu Diab or Safaja. This hill stands out boldly from the rest of the range on account of its very rugged aspect, and its three well-marked peaks which are visible for a long distance. It received the first name from a famous wolf, which according to Bedawi tradition committed great havoc amongst the people living in the vicinity of this hill, where he lived and for a long time evaded all attempts to kill him. The prefix "Abu" is attached to many names of persons and things by natives to indicate possession, thus, near this hill is the Wadi Abu Shia, i.e., the wadi possessing numerous bushes of "shia."

From Wadi Safaja the black foot-hills sweep round towards Jebel Nugara, at the base of which the coast-plain narrows almost to nothing, the sea running in quite close to the foot of the hills.

Wadi Safaja. This wadi when followed up after leaving the coast-plain becomes

very tortuous, winding in and out amongst rather angular ridges of a peculiar greenish satiny lustre. On the south, for a time, are the ends of the two ranges of Saga and Safaja, which rear their crests high above the other low hills, and dominate the country for miles around, the district between them being of the same type as the foot-hills on their seaward flank. In the wadi some well-grown trees of "seyal," as well as bushes of "markh," are found in the open spaces at the foot of the granite hills.

Well. In the range of Jebel Safaja or Abu Diab there are some pools of rain water which yield a fairly plentiful supply of drinking water.

After leaving the granite ridges behind, the wadi narrows and winds considerably through a complex of low hills of black rock which forms fairly steep sides. Higher up, the country opens out gradually by a steady fall in height of the surrounding hills, and a change in the character of the rock, which occupies all the district to the north as far as Jebel Nugara, from the base of which it slopes down towards a basin-shaped depression opposite the mouth of Wadi Wasif. This is occupied by two or three parallel ridges of limestone and sandstone which have been produced by faulting. This basin-shaped depression seems to be one of a series extending in a north-east and south-west direction to the north and south of the wadi. Here a tributary, called Wadi Maderaba, which heads in the low black hills to the north-west, joins the main drainage line. In this synclinal there is a good expanse of open ground owing its presence to the removal of the sandstone by denudation. Here two gazelle were seen on the day the camels arrived.

Wadi Maderaba.

Wadi Wasif. This valley enters Wadi Safaja on the outskirts of the sandstone patch. It comes from the area of black, steeply-ridged hills to the south-west, and contains pools of rain-water two or three hours' journey from its junction with W. Safaja.

After ascending Wadi Safaja for about two kilometres, the character of the country changes, the dark-grey or black rock which occupied the lower ground giving place to a greenish glistening, slaty-looking variety which weathers out into smooth, slippery, steep-sided hills of a fair height, gradually rising towards the mass of J. Abu Marwat.

Just before reaching the mouth of Wadi Abu Marwat, Wadi Safaja bifurcates, the main branch bending northward and heading somewhere near Jebel Abu Farad, while the road follows the smaller one up to the watershed.

Wadi Abu Marwat. This wadi enters the smaller branch of the main drainage line a little above the bifurcation above-mentioned, and drains the mass of high black hills to the south.

Water is found near its mouth in ordinary years, but in 1897 the pool was dry. **Well.**

The sides of the main wadi are very steep, the hills having become fairly high in this region, but from the mouth of Wadi Abu Marwat to the watershed, a distance of six kilometres, they become lower and lower until at the parting of the water they form only low knolls. The watershed, which slopes gradually towards the east, is extremely abrupt to the west, the descent being very steep. This, however, is not a very well-marked parting, as Wadi Semna heads further to the west, and the water which at first commenced flowing to the west sweeps round and enters Wadi Safaja on the east.

In the main wadi camel food and fuel are plentiful, there being many "seyal" and "markh" trees, as well as "bsilla" bushes, while along the more fertile parts of its bed two patches of very well-grown "Etal" trees were seen. **Camelfood, and fuel, etc.**

From the tops of the hills on the sides of the wadi a good view was obtained of the huge granite range of Jebel Barud and Ras el Barud, while nearer rises the steep and narrow ridge of Jebel Abu Farad.

Leaving Ras Safaja, Wadi Semna was followed for a short distance until the path turned off towards Ras el Markh, through a confused mass of low hills which occupy the country from the neighbourhood of Ras el Barud on the north, to the foot-hills around Jebel Jarra. From this point the road ran down Wadi Markh into Wadi Gareya and on to Qena.

E. *Return journey to Sea-coast from Fatiri.*—Before entering Wadi el Bala proper, a very rugged, precipitous pass has to be negociated, which is covered with boulders over which the camels have in many cases to jump. This broken ground covers nearly a kilometre, the gully at its head not being more than 15 metres wide, but gradually widening to 20 metres towards the foot of the pass.

Starting from the watershed this wadi runs into a large sandy plain dotted with low rocky mounds, which stretches away to the south in the direction of Wadi Semna and the head of Wadi Safaja. It then runs across this open country for about 7 kilometres, afterwards entering hills of a ridge-like character produced by dykes, which form the foot-hills of Jebel Abu Farad, eventually joining Wadi Barud. The first portion of this valley descends rapidly and has little vegetation in it. At the point where it opens out into the plain another wadi joins it which runs along the foot of a very steep and high mountain range, separated from Jebel Ras el Barud by a small sandy plain, and has (according to the guides) no name. It rises about 600 metres **Wadi el Bala.**

above the plain, and together with the latter hill forms a marked feature of the landscape.

Ras el Barud.

This hill serves as a very good land-mark, being visible and distinguishable from a long distance on account of its peculiar shape. It consists of three well-marked peaks of which the two northernmost are highest, the third being much lower. The two on the south side have flat tops which serve to distinguish them from all the other hills in the district. The range is composed of a red granite and exhibits its characteristic weathering.

Jebel Barud.

This range, commencing as it does on the watershed, lies to the north of the route, and extends as far as the coast-plain. It would seem as though it consisted of two parallel ridges, one behind the other, the northernmost being the higher. Being a granite range it exhibits the characteristics of this rock in a marked manner, its summit being a regular array of rounded and angular crests. On the side of the coast-plain it seems as though it becomes fused to Jebel Nugara on the one hand, and Jebel Mogher or Abu Moghat on the other. This range may be regarded as the southern limit of the granite massif which commences about latitude 27° N., as from this point northwards the low black hills, instead of occupying the major part of the country, dwindle into insignificance.

Wadi Um Tagher.

Leaving Wadi Barud on the north the road runs over a small plain containing many dyke rocks which give the country a ridgy appearance, from which by a steep descent over blown sand Wadi Um Tagher was reached. This valley heads in the plain a little to the south and runs in an easterly direction down to the pass through the ridge of Jebel Nugara, where it joins Wadi Barud.

Conntry round Wadi Um Tagher.

Starting from its head, the wadi first passes a granite range with very steep sides, through which the valley has cut its way, its course being deflected by a ridge containing a hard dyke. Beyond this point, and separated from the first ridge by low black hills, is a second steep-sided range, standing out from the surrounding country, both of these bearing the name of Jebel Abu Farad. From this point to Jebel Um Tagher the country on the south side consists of ridges of grey granite these being due in all cases to dykes, two sets of which occur running at right angles to each other, the east and west set dominating the other. The country is thus essentially made up of more or less parallel ridges having an east-and-west bearing. Beyond the granite area come the greenish, satiny, schistose rocks which form the sides of Wadi Safaja.

On the eastern side between Jebel Barud and Wadi Um Tagher, the ridge-like character is still more pronounced, one dyke in particular

being visible from the head of Wadi Bala to the junction of Wadis Barud and Um Tagher, a distance of 12 kilometres, its bearing being a few degrees south of east. Along the base of this ridge, according to the guides, lies Wadi Barud.

This is a precipitous hill of red granite, rising 279 metres above the wadi, and consisting of three peaks, the highest of which is almost inaccessible. From the summit a good view of the surrounding country was obtained; to the south rose the steep angular peaks of Jebel Abu Diab, and the ranges of Saga and Abu Shigeli, while to the east lay the ranges of Jebel Nugara and Barud. From the base of this hill the country suddenly opens out into a red sandy plain, extending to the base of Nugara, and covered with granite detritus, while a few granite knolls were scattered sporadically over it. Topographically it is very interesting, as it contains a tripartite watershed. About 2 kilometres from Wadi Um Tagher the first parting is reached, from which all the water passes north into the above-mentioned drainage. For the next 2 kilometres the plain was falling eastward and the drainage evidently runs out to the sea by a small wadi which runs round the base of Jebel Nugara; while from the west side of this parting the water passes through a black ridge of hills and descends rapidly into Wadi Maderaba. Jebel Um Tagher.

This wadi, which heads in the low ridges between Jebel Abu Farad and Jebel Um Tagher, is at this point an open gravelly plain sloping to the south, and bounded by low hills to the north-west and south-east, by the igneous range to the north-east, and Jebel Um Maderaba on the south-west. It receives a small tributary from Jebel Um Tagher which drains the western side of that hill. Finally, this valley narrows down to 0·25 of a kilometre in width, and bending to the south-west between Jebel Um Madaraba and some granite hills, flows into Wadi Safaja. Wadi Maderaba.

This is a range of low hills running first south-east and then south, and sloping gently down to the plain on either side, forming a continuous ridge 72 metres high and ending on the west in a hill 162 metres above the wadi. On its southern side is another gravelly plain whose drainage passes through an opening in the ridge into Wadi Maderaba. In the main valley, camel food is fairly abundant, but fuel is scarce. Well-marked camel tracks pass through this district, in nearly all cases going in the direction of Wadi Safaja, doubtless for the purpose of bringing water from the pools in the country to the south. To the south-west of Jebel Um Tagher there is a brackish well, the water of which can only be drunk by camels. Jebel Um Maderaba. Camel-food etc.

Wadi Um Tagher.

From the base of Jebel Um Tagher, this valley winds through a confused mass of low hills until it enters the pass of Wadi Barud, where it ceases to have a separate name.

Wadi Barud.

This wadi takes its origin in Jebel Ras el Barud from whence it descends in practically a due east direction towards the sea, until just before touching the seaward range of hills it turns sharply at right angles along its foot and finally passes through it in a narrow gorge. On its way it receives all the drainages from the southern range of Jebel Barud. There is a noteworthy fact about this valley, in that instead of taking what seems to be a much easier way to the sea, through the low ground at Wadi Abu Shalala it turns round at right angles and after running some little distance suddenly breaches the high range of Nugara by a narrow gorge bounded by sheer cliffs. This gorge* is undoubtedly an east-and-west rift along which the valley has been formed. When approaching this range from a distance it would seem as though the wadi is running against a dead wall, no sign of a valley being visible. Another anomaly is the persistence of this name to the exclusion of that of Um Tagher the rule for deciding which of two confluent streams shall be regarded as tributary being, that the one whose course is changed is regarded as the feeder, while the other is the main stream and preserves its name. According to this, Wadi Um Tagher ought to be regarded as the main drainage line, and Wadi Barud, which has been turned aside and enters from the north, the tributary.

Barud Gorge.

This gorge is about 6 kilometres long and varies in width from 50 to 120 metres. It presents a grand piece of scenery of the boldest and most rugged character, the sides being extremely steep and in some cases perpendicular, and rising about 600 metres above the wadi. Wadi Barud joins it about 1·5 kilometres from the western end. Any drainages entering the ravine are only torrents from the cliff, having a very steep fall, some dropping from a height of 200 metres or so above the bed of the wadi.

About 2 kilometres from the eastern end a boss of granite rises sheer from the bed of the wadi for 300 metres, and is continued for another 300 metres or so at a very steep slope. As this point is approached it presents a very imposing sight, the wadi turning sharp round its base seeming to end in a cul-de-sac. From the floor of the pass the hills could be seen towering peak over peak one above another in rugged grandeur. The lower part of the ravine is much strewn with boulders, rendering it somewhat difficult for laden camels, while there is a difference in level between the two ends of the gorge of 78 metres, although the fall is uniform throughout.

* See Photogravure No. 9.

CLIFF BOUNDING THE RAVINE OF WADI BARUD

To the south of this gorge the hills bear the name of Jebel Nugara. This is a red granite range which rises out of the surrounding country and occupies a commanding position on account of its many-peaked lofty summit, which is visible for over 80 kilometres. It extends from the sea-plain, which at this point is very narrow, to the low ground between Jebel Um Maderaba and the dark igneous range which bounds it on the south-east, and where it almost touches the sea. Some of the peaks near the mouth of the gorge rise from between 900 and 1050 metres above the wadi, while one conical peak, which is evidently the summit, borders on 1200 metres. To the north of the Barud gorge, the range, although continuous with that of Nugara, is called Jebel Barud; it is much lower than the former and gradually slopes down towards Wadi Abu Shalala where it becomes broken up into hillocks. **Jebel Nugara.**

This is a smooth plain falling rapidly towards the sea from the foot of the mountains, near which are a few hillocks and gravel mounds. Opposite the mouth of Wadi Barud is the island of Safaja, which viewed from the land appears to be lowlying, undulating, sandy ground with no well-marked peaks. **Coast Plain.**

A little distance to the north of this island the shore juts out into a conspicuous headland, named Ras Abu Somer, which encloses a well-marked bay, in which is a small coral island. The water according to the Admiralty's Chart is fairly deep in this bay being 36 to 25·5 metres inside the island above referred to, and between it and Safaja. **Ras Abu Some**

To the south of the island of Safaja, the axis of which lies north-west and south-east, i.e., parallel with the general trend of the shore, the water is also about 25 metres deep close in, while between it and the shore there are only 6 metres of water. It thus seems as though this island is slowly becoming joined to the mainland. It is also noteworthy that the coral reefs which usually follow the outline of the shore pretty closely, here pass outside the island.

From Wadi Barud a well-marked road was followed as far as the mouth of Wadi Mogher, where it was lost, probably on account of its bending eastward towards the coast. It is a well-defined track, about 12 metres wide, marked by heaps of stones at regular intervals of 20 metres on either side, which had evidently been collected to clear the path and make better footing. This road was seen at places south of Wadi Safaja, and is evidently the remains of a military Roman road from Suez to Qosseir and perhaps to Berenice. At places where the drainage from the hills crossed it all traces were obliterated, but it always reappeared further on. The next place where it was seen was near Abu Sha'ar where there are the ruins of a military station, and **Old Roman road.**

from that point it was followed along the sea-coast to the plain between Jebel 'Esh and Jebel Zeit, where it was lost, but it is continued over the plain to Bir Abu Nakhla.

Coastal Plain and hills bounding it.

This plain which, opposite the south end of Safaja island, is only 2 kilometres broad, gradually widens until at Wadi Mogher or Moghat it reaches a width of 12 kilometres. It is at first bounded on the west by Jebel Barud, which gradually falls towards Wadi Abu Shalala, where the plain runs back for some distance into the hills. Further north, Jebel Abu Marsala forms the boundary between Wadi Shalala and Wadis Morat and Mogher. Up to this point, the plain was practically a level expanse of granite sand and gravel, out of which rose isolated knolls of limestone, and across which the drainage from the hills spread itself as it made its way to the sea. A peculiarity of this district is the entire absence of foot-hills to the mountains, the plain running right up to their base, against which it stops abruptly like a beach against a cliff.

Wadi Shalala.

Taking the hill ranges and wadis in order from south to north, Wadi Shalala is the first to be described. It is a short drainage which takes its origin in Jebel Abu Shalala a few kilometres inland, and after winding through the confused mass of low hills bordering the plain, emerges from them and makes its way to the sea.

Jebel Abu Marsala.

The country between the above-mentioned wadi and Wadi Morat is composed of a very large and confused system of ranges, the heights of whose peaks vary from 600 metres downwards. All these up to the latter wadi are grouped under the name of Jebel Abu Marsala.

Wadi Morat.

This wadi forms the line of separation between Jebels Abu Marsala and Abu Morat. It takes its origin, according to the Bedawin guides, somewhere in the northernmost range of Jebel Barud, from which it receives the drainage, and lower down that of the hill-mass to which it gives its name. This information could not be verified as the wadi was not explored. A short distance from the mouth of this valley there is a well of brackish water drinkable by camels but unpleasant to people who are unused to it.

Wadi el Mogher or Moghat.

Six kilometres to the north of the previous wadi occurs another drainage called Wadi el Mogher or Moghat which drains the large hill-mass of Jebel el Mogher, the latter extending eastwards a distance of 14 kilometres, when it seems to join the hill mass of Jebel Um Kabbash.

Jebel el Mogher.

It consists at its eastern end of two ranges, a main and a secondary one which unite to the west. At the eastern end the main ridge rises 900 to 1200 metres above the wadi. Towards the centre there is a break in the range, the hills rising only about 300 metres above their

base, while at the western end they are about 800 metres above the wadi. The northern side of the range is very steep and precipitous, while the southern, as seen later from a distance, seems to slope gently towards the plain.

According to the guides, there is a pool of water in the main range, which appears to be in one of the tributaries of Wadi el Mogher. This wadi heads in the hill range about 16 kilometres from the edge of the coast-plain, and on its way to the sea receives many tributaries from different parts of the hill-mass. It has this peculiarity, that instead of making its way direct to the sea, by breaching the gravel plateau which here runs parallel with the hills, it turns aside along the edge of the scarp and runs parallel with it for about 10 kilometres, then making its way to the Red Sea. **Wadi el Mogher.**

Between this gravel plateau and the main hill mass, lies a sandy plain traversed by dykes of a doleritic rock, and dotted over with low knolls of red granite, in which many "markh" bushes, "bsilla," and "bowal" are found.

From the point where Wadi el Mogher enters the coast-plain, a low gravel plateau extends north for 10 kilometres to the point where Wadi Abu Garia descends to the sea. Further to the east this is seen to end against another plateau consisting of clay beds, which is continued down to the coast, and is broken up into a confused mass of low ridges with wide drainage lines running between them. **Gravel plateau in Coast Plain.**

Between Wadi el Mogher and the next wadi to the north (Wadi Abu Garia) there is a pass which can be crossed by laden camels, but is somewhat winding, most of the water from it going into the latter wadi. It is not a very long valley, and heads amongst the low foot-hills near Jebel Abu Garia. **Wadi Abu Garia.**

Nearly parallel with this drainage for a good part of its course runs the Wadi Um Kabbash, which heads in Jebel Um Kabbash, a hill-mass lying 9·5 kilometres from the coast-plain. After leaving its source, this wadi almost runs into Wadi Abu Garia, only a small ridge separating them, until about 4 kilometres from the coast-plain, it bends suddenly to the north, and receives another tributary from Jebel Abu Garia. From this point, its course again becomes parallel with that of Wadi Abu Garia, and the two then run down together to the sea. This country is a labyrinth of small wadis which are too minute to be shown. **Wadi Um Kabbash.**

The district drained by these wadis is a confused mass of low hills of grey granite interspersed with knolls of a fine pink variety. The hills show the well-rounded appearance characteristic of the weathering

of this particular granite. Numerous dykes traverse this district, the dominant ones bearing north-east-south-west. Camel feed is plentiful here, but fuel is scarce.

Between Wadis Abu Garia and El Mogher there is a small, narrow, isolated range with precipitous sides belonging to Jebel el Mogher, whose summit is about 750 metres above the wadi. From its base a series of foot-hills gradually decreasing in height extends to Wadis Abu Garia and Um Kabbash.

Jebel Abu Garia. This range is divided into two, the western half being the higher. It has a general trend north-east-south-west and is about 8 kilometres long, running up towards Jebel Um 'Anab. It consists of a series of flat-topped conical hills on the eastern end rising about 300 metres above the plain, while the western half is about 750 metres high. The whole of the large hill-masses are composed of coarse red granite, and accordingly are very similar in general appearance.

Wadi el Shayeb. Leaving Wadi Um Kabbash and its tributary from Jebel Abu Garia, the road crosses a small sandy plain bounded on each side by low hills, and passing Wadi el Shayeb, runs on to Wadi Um Dalfa. This wadi, according to the guides, heads in Jebel el Shayeb, and making its way in an easterly direction, down through the sandy plain which it drains, crosses the coast-plain to the sea. To the north of the point where it leaves the hills, is an isolated granite mass called Jebel Abu Bedun.

Between Wadi el Shayeb and Jebel Um Dalfa is a small range of hills rising 600 metres above the plain, for which the guides said there was no name, foot-hills extending outwards from its base for a considerable distance. Looking up between these ranges towards Jebel el Shayeb, part of a flat sandy plain was visible which is probably the same as that seen from the top of Jebel Abu Harif. (See p. 38).

Jebel Um Dalfa This is a very fine range of lofty mountains running in a north-west direction, and joining that of Abu Zogata which has an east-north-east trend, this in turn joining Jebel el Oman which runs westwards, the whole forming a large and imposing hill-mass. The southern part of Um Dalfa is remarkable for its peculiar shape, being very narrow and gradually rising towards the west, where the highest peak is about 900 metres above its base. At its foot in a sort of cul-de-sac on the southern side, and well shaded from the sun by the high vertical rock-wall, is a well of excellent drinking water. From a crack in the hill the water comes trickling down, apparently supplied from a pool higher up, as lichens and other moisture-loving plants were seen high up the mountain side. This pool seems to be much frequented by the Bedawin who bring their flocks and camels to drink from the lower

pool. The place from which the people fill their waterskins is at the foot of the precipice amongst huge granite boulders. Numerous plants were found near the water, amongst others the maidenhair fern (*Adiantum capillus veneris*), Lavender (*Lavendula coronopifolia*), "Lasaf," a kind of wild fig (*Capparis spinosa*), "Kit-kat" (*Francœuria crispa*), grasses of the Fescue family (probably an *Aeluropus*) and the sweet vernal grass resembling *Anthoxanthum odoratum.*

The remainder of the range is a series of high peaks rising out of a mass of low hills 450 metres above the ground-level, while the highest is about 1000 metres above the wadi.

This wadi heads in the hill-mass of that name, and runs in a south-easterly direction until it clears the hills, when it bends sharply at right angles east-north-east, and makes its way towards the sea. After leaving the hills it receives a tributary from the south-west, which drains the nameless group of hills to the south, as well as the ridge at the foot of which is the well. From the north-west it receives Wadi Abu Zogata, which drains the range bearing its name. On either side of the latter wadi the hills rise grandly, giving a very fine scenic effect. **Wadi Um Dalfa**

The hills in this mountain range are with one exception lower than those of Um Dalfa, that rising about 1050 metres above the wadi. The whole of this range was not visible, so its extent cannot be stated. **Jebel Abu Zogata.**

To the north of the previous hill-mass lies that of Jebel el Oman, which is quite different in character to the others previously described. It consists of a few isolated mountains surrounded by low hills, the principal peak rising in a majestic manner clean out of the plain, and there being no foot-hills, it forms a conspicuous land mark for a long way off. **Jebel el Oman.**

From the mouth of Wadi Abu Garia to Jebel el Oman, with the exception of Jebel Abu Bedun the whole of the foot-hills of the main ranges slope gradually down into the coast-plain on to the sea. There is thus a sharp contrast between the country to the south of Wadi el Mogher where the main ridges rise sheer out of the plain without any intervening foot-hills and that to the north, where a mass of foot hills is present between the mountain-range and coast-plain. **The Coast Plain.**

After leaving Jebel el Oman the coast-plain is reached, which here stretches in a practically unbroken expanse for 35 kilometres to the seacoast at Abu Sha'ar. From this point foot-hills again appear on the edge of the plain, and stretch away up to the base of Jebels Gattar and Minfeih, their highest point being about 150 metres above the valley. As the high mountain ranges are approached the small hills decrease in number, and eventually the country becomes a sandy plain with

hillocks. Towards the coast-plain, the hills assume a ridge-like character similar to that seen in Wadi Fatiri, while further north they decrease in size, eventually being reduced to sandy mounds and disappearing under the plain, which extends from Jebel Dokhan down to the sea without a break.

Wadi Mattur.

Out of these foot-hills comes a watercourse named Wadi Mattur, which according to the guides heads in Jebel Abu Mattur.

Abu Sha'ar.

Crossing the plain from Wadi Mattur, after a march of 23 kilometres the plateau of Abu Sha'ar is reached. It consists of a limestone plateau rising abruptly from the plain to a height of 150 metres, and gradually merging into the latter towards the west. On its south and east sides it presents a bold, steep escarpment, near the southern end of which is a well-built "rigm" or cairn. At this point the old Roman road was again struck, and was followed until the plain to the north of Jemsa Bay was reached, where it was lost.

In the cliff are numerous openings to allow of the discharge of the drainage. These in nearly every single instance end in a series of cataracts, none of them, except the Wadi Belih, being cut down anywhere near ground level. This is important when the tectonic changes come to be considered in the geological section of this memoir, as it throws a strong light on the kind of movements which have taken place, and lends weight to the idea that the deep wadis such as those of Belih, 'Esh, and Mellaha, are the result of east and west rifts (p. 215).

The whole plateau may be taken as having the shape of a very obtuse triangle with its apex at the south-east corner.

Bir Abu Sha'ar.

Two kilometres from the apex of the plateau is Bir Abu Sha'ar. It consists of two pools in the sand at the foot of the cliff, one holding about eight to twelve litres, while the other contains eighty to a hundred. When the water is drawn out of these pools they fill up again in a few minutes. Round about the wells are several palms, tamarisk bushes, and a few rushes. The water is nice and clear, and apart from its being slightly brackish is not unpleasant to the taste.

Old Roman rest-camp.

On the sea-shore opposite the "rigm" or cairn on the plateau were found the ruins of what seemed to be an old Roman rest-camp. The whole of the walls were in a ruinous condition, but there was sufficient left to give an idea of the general plan of the building. Standing in front of an opening facing northwards, two heaps of bricks were seen at each corner, these being probably the remains of two watch towers, and there were two others on either side of the gateway. Outside the ruinous wall the remains of a fosse could be seen on two sides at least, while that on the other two is probably obliterated by the moving

sand. Inside the fort the plan of the houses could in many instances be made out, the size being 3·5 by 4·5 paces. The inside measure of the fort itself was 66 by 80 paces. The number of houses crammed into this space is wonderful, as many as ninety being counted. Besides these there was an open space in the centre evidently used as a barrack square, and opposite to this there had been a well which is now filled up by sand and debris. The plain between Abu Sha'ar and the sea was flat and sandy, becoming more gravelly further down. Near the sea were a few tamarisk and other bushes, and in the water-courses "bowal" and other plants grew in fair abundance.

Wadi Belih. At the place where this wadi debouches on the plain it is bounded on either side by black andesitic hills, capped by limestone. There is a fairly large break in the plateau at this point, some small hills lying between the two main cliffs. This continues for about 2·5 kilometres, when the sides close in and become steep and precipitous. The wadi proper averages about 30 metres in width, and in the first three kilometres it changes its direction eight times as it passes through the low hills, some of which rise 90 metres above it. Higher up the two cliffs approach each other until they are about 50 or 60 metres apart. After leaving the igneous rocks behind, the sides of the ravine are formed of almost vertical limestone cliffs from 60 to 90 metres high which were unscalable. As the wadi was followed up, the sides became gradually lower and the plateau began to break up into isolated mounds rising about 60 metres above the valley, these gradually merging to the westward into the level of the plain, which extends a distance of 16·5 kilometres to the point at which the hills again begin. Scattered over this plain are isolated granite knolls shewing east and west dykes running through them, while nearer the hills these features become more prominent. About 5·5 kilometres from the edge of the hills the road from Jebel Dokhan to Jebel Zeit was struck and followed up to the wells of Dokhan or Beidia, where the other surveying party was met.

Wadi Belih heads in the hills near Dokhan. It is interesting from a tectonic point of view as being an example of a valley formed by an east and west rift, no other explanation being possible, seeing that the drainage here is extremely recent. Other parallel examples of this sort are forthcoming in Wadis 'Esh, Mellaha, and Dib.

The whole of the drainage of the plain passes down into Wadi Belih, Wadi Um Sidri entering it also. From the plain the following hill-masses were seen:—Beginning from the north the first is Jebel Kufra, Um Messaid, Abu Harba, Um Sidri, Dokhan and Gattar, while to the south are the peaks of El Shayeb, and Ras el Barud.

Great Plain. Leaving Bir Dokhan the road to Jebel Zeit via Bir Mellaha was followed across the wide plain. Along the edge of the foot-hills large mounds of gravel and boulders run out in tongues into the plain, while they gradually tail off on the slopes of the igneous hills, rising 45 metres above their base.

About 18 kilometres from Bir Dokhan along the Jebel Zeit road a path was crossed running south-east and north-west, which according to the guides ran up to Kufra, an old ruined village near the hill of that name.

Three kilometres further north a road leading to Gharib was passed over, and a little further on, the old line of telegraph which once connected Qena with Jebel Zeit and Jemsa was struck and followed as far as Bir Mellaha. Many of the posts are still standing, but numbers have been pulled up and used as fire-wood by the Arabs, all the wire and insulators having been taken away.

The whole of this plain is covered with a thick gravel deposit in which shallow water-courses have been cut, and through it the drainages from the igneous hills flow towards Wadi Mellaha. Wadi Kufra rises in Jebel Kufra and runs in a north-easterly direction, while further to the north Wadi Abu Marua comes from Jebel Abu Marua, and lastly Wadi Mellaha descends from Jebel Mellaha, which after receiving these others makes its way through the limestone ridge of Mellaha and the igneous range of 'Esh to the sea.

Jebel Mellaha. This is a limestone range commencing nearly opposite the head of Wadi 'Esh, and running in a north-westerly direction, which is breached by Wadi Mellaha near the well bearing that name, a little distance beyond which it changes its name to Jebel Dib. The length of this range from the southern end to Wadi Mellaha is 18 kilometres. On the east it presents a steep, abrupt scarp from which a few foot-hills run out into the plain separating it from Jebel 'Esh, while on the west side it slopes gradually down to the plain, being prolonged a little by a broad band of foot-hills of marl capped by limestone gravel, varying from 75 to 90 metres in height.

Bir Mellaha. These wells* occur in the bed of Wadi Mellaha between Jebel Mellaha and Jebel Um Dirra, about 1 kilometre from the foot of the latter hill. They seem to be true springs, as water trickles down the wadi continually, and pools are found here and there below the wells. It is interesting to note that here as at El Geita, and in the Oases of the Western Desert, the wells occur in the Nubian Sandstone. Round them there is quite a profusion of vegetation, consisting of "Tarfa," palms and bulrushes, the latter in abundance. The "tarfa" bush is also extremely common and

*For analysis of the water see Appendix I, p. 291.

occurs all down the wadi, in fact for about ·75 of a square kilometre the ground is covered with all kinds of plants. The surface is covered with an incrustation of salt all round, and the water has a decided salt taste, so much so that the camels refused to drink it, while some of the camel-men, who, having run short of water, were compelled to use it for a day or two, became ill in consequence. The wells consist of three or four holes about a metre deep, dug out of the sandy clay in the wadi, into which the water percolates, and which are protected from the sun by bulrushes between 3 and 4 metres high.

Plain between Jebel Mellaha and 'Esh.

After passing through the limestone range of Mellaha a plain is entered which varies in width from 3·5 kilometres at Wadi Mellaha to 1·5 kilometres near the head of Wadi 'Esh. A few small foot-hills lie here and there in it, but they gradually disappear towards the south. This plain owes its origin to the weathering of the Nubian Sandstone, and the drainage from it runs down into Wadi Mellaha whose bed seems to be in its lowest part.

There is another small wadi which heads near by in the igneous range near Jebel 'Esh, and runs parallel with the drainage from the plain, being separated from it by a low ridge of igneous hills and eventually flowing out through the Um Dirra range.

From the north, drainages from Wadi Gemalein and the other branch of Mellaha come down and join the Wadi Mellaha.

Um Dirra range.

This range, together with Jebel 'Esh on the south and Jebel Mellaha on the north, forms a ridge of igneous hills, 6 kilometres wide at the southern end, and 4 kilometres in the middle stretching from Abu Sha'ar to the north end of Jebel Abu Had which is the continuation of Mellaha, a distance of 80·5 kilometres. It trends in a north-westerly direction, running parallel with the general shore line, and is 305 metres above sea-level. On its seaward face it rises very abruptly from the plain, being faced in many places by a steep coral reef, while to the west it gradually slopes down to the plain which separates it from the limestone range previously described.

Jebel 'Esh.

The hills in this part of the range are much loftier than those of Um Dirra, the central peaks rising from 300 to 450 metres above sea-level, while on the seaward side a rugged and precipitous range of granite 160 metres high comes between them and the sea.

Wadi 'Esh.

This wadi heads in the plain lying between the igneous and limestone ranges. It is a narrow and tortuous defile bounded on either side by precipitous hills which increase in height as the coast is approached. A well-marked camel-track coming from Wadi Um Ṣidri goes down this valley, which in places is impassible on account of small precipices

except by a narrow path along the side of the hills, but further down it widens and the bottom becomes free from boulders.

Wadi Mellaha. The main Wadi Mellaha cuts through the limestone chain at right angles, exposing cliffs of limestone with regular layers of flints, on both sides of the valley. Camp was pitched in the more open part of the valley, not far from the well, closely associated with which are shallow pools of extremely saline water. The wadi then cuts through the granite, forming a picturesque gorge, bounded by precipitous cliffs. The ravine, about 3 kilometres long, is practically a reedy marsh throughout its course, palm-trees being numerous, while the reeds and rushes, growing in pools of salt water, sometimes fill the whole valley. In addition, graceful "tarfa" bushes add to the beauty of the scene, while hundreds of fish-hawks and other birds have their home in the cliff. Wadi Mellaha, on issuing from the gorge, runs between low ridges towards the sea, finally expanding into a wide plain. Just at the mouth of the ravine the hills change their character, a yellow-brown limestone ridge 90 to 120 metres high forming the boundary to the granite, and running parallel with the main range. This ridge forms one of the most conspicuous objects to the east of Bir Mellaha, its flatter outlines contrasting strongly with the lower granitic ranges.

Wadi Gemalein. Further to the north, where the road to Jebel Zeit and Jemsa crosses the range, there is another wadi bearing the name of Gemalein. There is a water-parting towards the west side of the range, the western part flowing down into Wadi Mellaha, while the other flows straight into Ghubbet Jemsa.

Sea Plain. The coast-plain east of this range consists of mounds of sand and gravel of the same nature as those to the east of Abu Sha'ar. Opposite Wadi 'Esh it is about 9 kilometres wide, but it narrows suddenly to a little over one kilometre where the sea sends in a tongue about half-way between Jebel 'Esh and Um Dirra, from which point it gradually widens out, until opposite Jebel Mellaha it attains the width of 5·5 kilometres. Opposite the mouth of Wadi Gemalein, the coast bends sharply at right angles and runs north-east towards the neck of Jemsa Point, the plain becoming 11 kilometres wide. Along the sea-coast there is a belt of salt mud which is covered by the sea at high tide, and during the time when it is exposed to the sun, a hard crust forms which makes it very unsafe for camels to walk upon it, as it gives way and the animals slip about in a most helpless fashion, to the danger of their limbs. Just outside this band, numerous "asal" bushes, (*Suæda monœca*, Forsk.) which seem to thrive well in a salty soil, grow in abundance.

This consists of two narrow spits of land, one 3·5 and the other 6·5 kilometres long, running out into the sea. The shorter of the two is composed of a mass of low hills of gravel about 27 metres high gradually rising to 48 metres at the extreme end, which consists of gypsum rising sheer out of the water. The other, when seen from a distance, appears to be an island, the connecting neck (15 metres high) not being visible. It terminates in a hill called Jebel Kabrit, so named from the sulphur mines which occur there. Towards the west this hill presents an abrupt face, while it slopes down more gradually to the south. Here are seen the remains of some buildings which were erected for the working of the oil and sulphur which occur at this point. Many pieces of plant are still to be seen, as well as the light railway which was used for putting the sulphur on board the boats. The shafts and galleries driven at various parts into the hill are still in fair condition, and a pool containing a thick tarry liquid is seen in one of the latter. **Jemsa.**

The plain between Jemsa, Jebel Abu Had, and Jebel Zeit varies from 14 to 23 kilometres in width. It is covered with low gravelly mounds about 18 metres high, and is much cut up by water-courses. At the point of origin of Jemsa neck, evidence is present to show that very recently the sea actually covered it, leaving Jebel Kabrit an island. **Coast Plain.**

Passing round Zeit Bay the road ran across several deep pools of sea-water which reached the camels' hocks. For a good distance inland the land was soft and muddy, while seaward the water was shallow for over a kilometre. It is evident that here at least there is an upward movement going on.

After the parties separated at Bir Mellaha, one followed a route which ran north-west up a side-valley of Mellaha about 2 kilometres broad, bounded on the west by a white continuous ridge of limestone bordered by low foot-hills, and on the east by a line of igneous hills running parallel with the limestone range, the granite crests near Bir Mellaha being soon succeeded northward by summits of more rounded or conical outline with long ridges, and darker in colour. The most prominent peaks in the Abu Had range, are part of a high coral limestone ridge, which flanks the igneous mass on the eastern side, the latter being only a thin belt at this spot.

Wadi Abu Had runs from the El Adid el Gadan range in the main Red Sea Hills, crosses the Great Plain, breaches the limestone and Jebel Abu Had in succession, and finally opens into the coast plain in which it is to a great extent lost. The further route lay through the Abu Had hills by this valley. North of the Abu Had ravine in the **Wadi Abu Had**

igneous chain, a bold range of granite or syenitic mountains rises through the darker basic hills, while where Wadi Abu Had opens out into the plain, yellow limestone hills flank the darker igneous ridge (see panorama III).

Zeit Bay. The neighbourhood of the bay shows signs of comparatively recent elevation, raised beaches extending for some distance inland. The ground, too, in many places, is soft and marshy some distance beyond the tide line, and long shallow arms of the sea penetrate far inland. The water within the bay is also shallow, the greatest depth noted being 8 fathoms, whereas, along the cliffs to the north, it often sinks rapidly to 30 or 40 fathoms with only a thin belt of shallow water within the coral reef. While the camels went round the side of the Jebel Zeit hills to the old station there, the range was examined, which even from a distance has a striking appearance, owing to the dark igneous rock forming the higher peaks being completely surrounded by yellow or white-looking gypseous beds. These latter can only be entered at one or two points by large wadis. They are traversed in all directions by small gullies, so narrow that the walls can often be touched on both sides, and usually terminating in an abrupt precipice 3 to 6 metres high, formed by streams cutting back. This habit makes the examination of these hills somewhat difficult, as the cliffs on both sides are usually very steep at these points and the gypseous rock brittle, affording insecure hand and foothold, and in addition the gypsum weathers into sharp projecting needle-like pieces. In the centre of the chain is a valley broadening out at one spot (see Plate VI) and then running parallel to the igneous ridge till it enters the plain at the south-east end of the chain. The road here winds round to the eastern side, crossing over low ridges, while a broad flat promontory juts out beyond the hills in the same direction forming the northern boundary of Zeit Bay. On the eastern side of the Zeit range, the gypseous hills form a thin belt on the sides of the igneous rocks, while between them and the sea lies a flat plain terminating in a low cliff 6 to 9 metres high. Just above tide-level there is a second drop of about a metre, and at some points a third flat coral ridge runs below the water level, but at Zeit itself there is a sudden drop into 9-10 fathoms of water. Near the edge of the sea were some ruined buildings belonging to the former petroleum works, and opposite these is a small coral island covered with circular belts of low bushes. Behind the houses in a plain is a road, still in good preservation, running to the source of the petroleum (see Plate VI).

The petroleum is present as a dark oily mass in two artificial cuttings, but in one the oil only floats on the surface, the remainder being water.

Some deep grooves have also been cut at right angles to the shore in the coral reef, but apparently with no success as regards the finding of petroleum, which probably owes its origin to the decomposition of organic matter in the shell beds. Sulphur and carbonaceous matter are present in the limestone a little above the well. At Zeit it was necessary to send the camels for water to J. Mongul, the nearest point at which drinkable water is obtainable. On the return journey, while the camels went round the hill, both survey parties crossed the range.

The track, after leading across the gravel plain enters a steep narrow wadi, or fissure, in the gypseous series, but no true path exists. The igneous hill to the north of the track was ascended, height 239 metres*; while a gypseous hill close by rises to 243 metres, this height however, being exceptional. A second hill was also visited to the north-east of the previously ascended igneous mass, this also appearing as an island in the middle of the gypseous hills. The camp in the plain was reached by one of the winding and precipitous wadis, the only easy one to the central plain having been missed. Low gravel ridges run parallel to the gypseous series on its western boundary. Behind Jebel Zeit extends the wide plain of Dib, which is bounded on the south-west side by the Abu Had range, on the north-east by Jebel Zeit, and extends in a north-west direction towards the Mongul and Dara mountains, though the main drainage sweeps round as a continuation of Wadi Dib, opening to the south of J. Mongul. The main route skirts the hills, whence the northern part of the Zeit range was examined. At this point it is bounded on the western side by low gravel foot-hills, then follows the gypseous mass, penetrated by two winding wadis, easily identified by the igneous fragments which lie in their drainage lines. Behind the gypseous hills is a valley running parallel with the chain due to the wearing away of the sandstone, which rises to the north in higher summits. The backbone of the chain is formed by a deep brown-red syenite crest of wedge-like form, rising to heights of 350 metres above the valley, and having very steep slopes on both sides†. From here a whole day was spent in crossing the plain, which is only broken by a few low ridges, though to the right (seaward) a higher limestone plateau was visible. At Abu Nakhla, where the camels had

* By aneroid.

† See Panorama IV.

to be sent from Jebel Zeit to drink, the water is very poor and brackish, being in a small hole dug in the shales of the gypseous series. Near it are a few palm-trees, from whence the name is derived. North of the well, ridges of cavernous limestone and ferruginous ochre border a wide plain, which is bounded to the south and west by low igneous hills, and to the north-east opens out, while the limestone forms well-marked ridges to the northward (for actual direction see plate I). In the centre of the plain are a few isolated sandstone outliers. The country between here and J. Mongul may be generally described as wide plain alternating with parallel ridges running north-west and south-east. T.B.

Section VI.—SUMMARY OF TOPOGRAPHICAL RESULTS.

Having now dealt with the country examined in some detail, it will be advisable to emphasize the wider points, which might be obscured by less important facts.

There is no doubt that the broadest features in this area owe their origin to tectonic changes of enormous magnitude occurring in comparatively recent times, and the result is a striking contrast when the Eastern or Arabian Desert is compared with the almost undisturbed expanse on the west of the Nile, unbroken as the latter is by any prominent ridge for hundreds of kilometres. The Arabian Desert, on the contrary, is a wilderness of ranges rising from 1000 to 2000 metres, surrounded or flanked by a maze of low hills of varied form and colour and only towards the Nile showing the broad plateau character and abrupt escarpment so familiar in the Nile Valley itself.

1.—*Length of Wadi Qena, etc.*—Nevertheless there are flat expanses in this region, but characterized by their great length and comparatively narrow width. Thus the upper part of Wadi Qena and the western plains have been proved to extend for over 200 kilometres from near the Galala hills in the north to the watershed near Qena-Qosseir road on the south, though their breadth rarely exceeds 20 kilometres. Similarly, the coast-plain of the Gulf of Suez and the Great Plain east of the Red Sea Hills extend for about 50 kilometres in a north-west direction, but as regards width agree with Wadi Qena. Otherwise there are no important level areas in this region.

2.—*The main Western Drainage of this area opens at one point only, viz. Qena itself.*—It has been shown that whatever the original direction of flow, all the drainage systems sooner or later join Wadi Qena, and thus enter the Nile Valley at that town. Of particular interest

in this respect is the drainage of Wadi Fatiri and the Nagateir plain, which starting from near the southern point of Abu Had, runs north along the eastern flank of the latter then bending completely round its northern edge, turns due south again, and follows the western border, thus curving completely back on itself.

3.— *The highest ridges of the Red Sea Hills are near their eastern edge.*—Practically almost all the most important summits are either on the eastern side of the watershed, or more rarely form part of it, Jebel Sobeir being the only exception of any note, while many of the main summits rise abruptly from the plain, or are at most, flanked by low foot-hills. This character is probably due to the eastern edge of the hills being the wall of a fault, the cliff produced being too steep to allow of the formation of long transverse valleys.

4.—*The Red Sea Hills are not one continuous chain, but a series of ranges, advancing in echelon, each new longitudinal massif to the south being further east, though remaining parallel to its predecessor.*—Though it is difficult to see precisely why this remarkable topographical result should be produced, it seems to be in intimate connection with the crossing of longitudinal and transverse fault systems, at least in some of the cases observed.

5.—*The association of longitudinal and transverse rifts has given rise to mountain blocks.*—Two striking cases need only be mentioned here, the central range of Gattar-Atilmi rising sheer over 1000 metres above Wadi Belih to the north, and having an abrupt wall 600 metres high facing Wadi el Atrash to the west, while on the east Jebel Atilmi itself towers above Wadi Minfeih. Only to the south is the system to a certain extent incomplete. Jebel Gharib is still more striking, it being entirely cut off from the remaining hills by two transverse and a cross-cutting longitudinal valley. Though direct evidence is scarce, it is practically impossible to avoid the conclusion that both valley systems are rifts or faults, and not produced by simple erosion.

6.—*Parallelism and repetition of the Jebel 'Esh and Zeit ranges.*—If the previous features are to a large extent inferred to be due to faulting, etc., there is no doubt that those now considered are directly due to movements of this nature, the ranges in question being parallel to the Red Sea Hills and Gulf of Suez, and showing distinct evidence in each case of a let-down on their eastern flank, whereby a depression is produced. Thus the Red Sea Hills themselves overlook and are parallel to the Great Plain; the coast plain separates the similarly related ridges of 'Esh and Zeit, and the latter follows the borders of the Gulf of Suez itself.

7.—*Transverse and longitudinal fissures give rise to limestone plateaux separate from the main plateau in Abu Had and Serrai.*—This fracturing just commences in this district, but is carried still further in the region south of Qena, the isolated ridges separated by low gravel plateaux standing in sharp contrast to the bold and continuous Eocene escarpment on the western side of the river.

8.—*Strike-Faults have given rise to remarkable topographical complexity near Qosseir, owing to the strata affected having independent scenic characters.*—As has been stated, the country in the neighbourhood of the Duwi range, etc., becomes in consequence a bewildering maze of limestone plateaux—the flat tops of which being now tilted are grooved and scored with ravines on the dip-slope—deep red-brown masses of sandstone, sharp ridges of red granite, and a complex of low dark, meandering and wedge-topped hills of diabase and ash.

In addition to the effects produced by the tectonic changes there are others due entirely to the nature of the strata.

9. *The Eocene limestones where undisturbed in all cases give rise to flat-topped plateaux* which face the valleys with bold escarpments, or where cut through by them, frequently rise in sheer vertical-sided walls on both sides.

10.—The Esna shales at the base do not directly give rise to a special type of scenery, but where present under the hard limestones greatly enhance the effects of faulting, while by their more rapid weathering they have been instrumental in the production of the secondary plateaux of Cretaceous limestone at the foot of the main escarpments.

11.—*The Nubian sands and softer sandstones are the chief cause of many of the great plains and minor valleys.*—In addition to the cases previously mentioned, the long depression which separates the Mellaha limestone range from Jebel 'Esh owes its origin entirely to the denudation of these sands, and the same holds true for Wadi Abu Zeran, running parallel to the Duwi range near Qosseir.

12.—Dykes have an important effect in the lower country bordering the Red Sea Hills, giving rise to a number of long parallel ridges with red crests or black outlines, while inversely, the softer diabases, by their rapid wearing away, are in many cases the cause of gullies, as in Wadi Atilmi.

13.—*Red Granite is one of the principal mountain-formers in the Red Sea Hills*, rising in steep slopes from among the lower foot-hills, but in view of the complexity introduced by faulting, it is often difficult to say how far these masses are intrusions, which have

withstood denudation better than the surrounding rocks. Its characteristics are either very sharp precipitous peaks, or when more denuded, rounded outlines.

14.—*A grey gneissose granite forming the lower country in the northern part of the district gives rise to a peculiar bouldery type of scenery*, resembling that seen near the First Cataract at Philæ and Assuan. This type is often closely associated with the dyke scenery.

15.—Where the volcanic rocks are present, the hills are less rugged, the valleys are often smooth, the outlines are more monotonous, and the colour is a nondescript-green, which eventually has a depressing effect. To the north in J. Dokhan, etc., they form high mountain groups, but to the south produce a characteristic labyrinth of tortuous valleys and meandering ridges.

16.—Finally, to the extreme south, the gneisses form the bold ranges of Meeteq, the precipitous peaks of which, broken into splintery crests, recall some features of Alpine scenery, though on a smaller scale. W. F. H. and T. B.

Section VII.—GENERAL REMARKS.

It might have been supposed that a country so barren and waterless as that under consideration would have been practically left to a few wandering nomads, obtaining a scanty subsistence for themselves and their flocks in the higher valleys, and to scientific travellers who find objects of the highest interest in apparently the most unfavourable surroundings, but as a matter of fact, these regions everywhere show traces of the activities of past civilizations. It is apparently generally considered that the original Egyptian races entered Africa by way of Qosseir, and it is certain that both the main and the northern roads from Qena to Qosseir were in use as early as the Fifth Dynasty, as Lepsius had obtained inscriptions of that age in Wadi Hammamat and the Sa-u-ra (the king who erected the large northern pyramid of Abusir) cartouche squeezed by Green in Wadi Hammama proves to be of the same period, while many other hieroglyphs show that the northern road was in active use during Egyptian times, and attention has been called in the previous pages* to the well-preserved cartouche of Ramses III. on the dolerite in Wadi Atolla. Many of the rocks, too, used in the Egyptian sculptures show very distinct evidence of having been obtained from the neighbourhood of these main roads, but as far

* See p. 52.

as known to the writers the Egyptian influence or research does not seem to have extended very far north, in the desert itself inscriptions of that age being entirely absent north of lat. 27° N. Indeed apart from those described by Dr. Schweinfurth* from Wadi Jasus north of Qosseir, no other notable ones occur, though the recent discovery of fragments of a beautiful Imperial Porphyry vase of early Egyptian date at Ballas by Quibell raises the question whether in part at least the ornamental rocks may not have been known to the early empires. It is most probable, however, that this vase was made from one of the many boulders of this rock occurring in the gravels near the cultivation. Similarly, no Persian inscriptions have been noted north of Wadi Hammamat, where Darius, Xerxes, and Artaxerxes are specifically mentioned, while on the sea-coast itself the Egyptians appear to have worked the petroleum of Jebel Zeit, and Myos Hormos was possibly a port as early as the time of Solomon.

Qosseir appears to have been an important harbour during both early Egyptian and Ptolemaic times, being known first as Fua, and afterwards as Leukos Limen, while Old Qosseir, a little over six kilometres to the north, formed the port of Philotera, so named in honour of the sister of Ptolemy Philadelphus.

But it is during Roman times that the whole of the Red Sea Hill districts first began to play an important part in general history, this area, judging from the Semna inscription, having been systematically controlled by special officers with a view to the development of its resources. As a result the quarries of red porphyry were opened at Dokhan, the beautiful hornblende-granite of Mons Claudianus was carved out into pillars, sarcophagi, and altars, the Semna valley also yielding ornamental stones. In addition the Romans appear to have been diligent searchers after iron ores, which have been extensively exploited by them in Wadi Abu Jerida, Wadi Jidami, near Jebel Abu Marwat, and Abu Garahish, and to the north in Wadi Dib. They are in addition known to have worked the petroleum at Jebel Zeit. As convict labour was employed, the main roads used by them are easily recognized by the number of old forts, or "deirs" occurring scattered throughout the desert, the most important, in addition to the main Qena-Qosseir road, being as follows:

(1) *Qena to Dokhan.*—Easy tracks lead from the porphyry mountain to the Nile at Qena, the road being guarded by a series of stations the most noticeable of which are the small fort near the watershed in Wadi

* SCHWEINFURTH, G., *Alte Baureste und hieroglyphische Inschriften im Wadi Gasus.* Abhand, Kœnig, Preuss, Akad, Wissenschaft, Berlin, 1885.

Gattar, the large building at Deir el Atrash, and the station of El Heita, which standing on the corner of the low hills projecting from Abu Had, commands all the passages round that hill.

(2) *Qena to Mons Claudianus.*—This road is less well-marked though buildings of various kinds occur in the Hadrabia hills and Wadi Fatiri itself, while near Mons Claudianus they increase in abundance, evidently with a view to preventing the escape of the workers.

A cross-road through the central range connected Dokhan with this station, small buildings occurring at intervals along Wadi Ghoza, and near the pool at Um Disi. Wadi Semna similarly contains a large stone "lokala," while speaking generally, wherever Roman mining operations have taken place, small square stone buildings are sure to be present. Schweinfurth's description of Mons Claudianus and map of Dokhan give an excellent idea of the character of these stations, which bring up a strange vision of past life and action where now all is silence and desolation. In addition to Qosseir, Queh and Myos Hormos (south end of Abu Sha'ar) appear to have been ports of importance, possibly even in Egyptian times, the latter being a place of call for the porphyry, while the little opening at Jebel Zeit would also have been utilized. Judging from the inscriptions the period of greatest Roman activity occurred during the reigns of Trajan, Hadrian, and Nerva.

Once more the desert became peopled when the great monastic movements began in Egypt, the silent waste being considered specially suitable for meditation and separation from worldly pursuits. The chief relic remaining of this by-product of the first centuries of Christianity in this district is the large ruined convent in Wadi Gareya, though when visiting the porphyry quarries at Dokhan, Hardwick found a slab bearing an inscription of the Catholic Church.

From the earliest periods the desert seems to have been peopled by nomadic Hamitic races, the ancestors of the Ababda and Bisharin who wander among its mountains and hills at the present day, and Dr. Schweinfurth has suggested * that to them is owing the introduction of the camel as a beast of burden, which, as Golenischef has shown, was known to the Egyptians of the Middle Empire. In the same valuable paper, Dr. Schweinfurth considers that they also were the first to tame the wild ass which still roams in the Nuba Hills, and it is certain they remained a perpetual menace on the borders of the rich and civilized regions, ready to indulge in predatory raids immediately the state showed signs of weakness. Thus at the beginning of the Christian era two

* *Bega Gräber, Verhandl. der Berliner anthropologischen Gesellschaft,* July 15, 1899, p. 552.

races, the Blemmyes and Megabara, are mentioned as inhabiting the desert region, while the Red Sea coast itself was occupied by the Troglodytes or cave dwellers.

While, as has been seen, the first and second centuries are here periods of quiet and industrial activity, the Blemmyes invaded Upper Egypt in A.D. 273, though five years later Probus repelled the attack, but from this time onward they were constantly on the border, and Dr. Schweinfurth has mentioned several historical facts of interest in this connection such as the payment of a subsidy by Diocletian, the sending of an ambassador from them to Constantine, and the capture of Nestorius during a raid, when the latter patriarch was exiled and living in the Oasis of Kharga. The Blemmyes seem to have been ardent enemies of the Christian faith, and it is to them, rather than to the Mahommedan invaders, that the destruction of the Gareya monastery must be ascribed.

Nevertheless, they appear to have readily embraced the Muslim creed, though the Ababda seems to carry his religion far more lightly than the Maaza tribesmen to the north. These, as representatives of the invading Semitic Arab races have apparently never been able to extend their influence far south of the Fatiri road, and even at the present day seem to be gradually falling back north before the more active Ababda race, whose members scorn to call themselves Arabs, and always refer to the Maaza in terms which indicate considerable contempt for their mental capacity.

From the 7th century till the beginning of the 19th, but few traces of the great outside movements are found in the desert, though the tribe of the Maaza had established itself to the north of lat. 27° N. During this long period the port of Myos Hormos and Old Qosseir had fallen to decay, Qosseir alone remaining as an important point in connection with the Mecca pilgrimage and Arabian trade.

Here and there are found traces of the unfriendly feeling which evidently existed between the two tribes, wells being stopped up; and there still exists a strong opposition on the part of the Maaza to the entry of an Ababda into the country forming their sphere of influence, the contrary also holding good. The characters of these tribesmen differ greatly, the Maaza being far more suspicious and reserved than the Ababda. Thus while the latter were eager to impart information, keen lovers of natural history, as evidenced by their knowledge of the smallest plant or distribution of the animals, revelling in fantasias when opportunity occurred, and the younger members full of high spirits and good humour, the former at first were little inclined to describe

the country, knew but little about the fauna and flora beyond what was required for daily needs, were in general reserved, cold, and rigid in following the regulation prayers, etc., at the same time being more superstitious. In one case the sheikh of one party persuaded his men not to be photographed assuring them that it was very bad, but it must be added that many of the Maaza have a dignity and reserve which is worthy of admiration, and after the first few days seemed anxious to help in every way.

The desert once more emerges into the light of history at the end of the 18th century, when Napoleon was endeavouring to carry out his vast plans for the destruction of the British power. Two French expeditions seem to have advanced into this region, one going from Qena to Qosseir, while the other examined the country north of Gharib. An English expedition also landed at Qosseir, and marched to Qena, but the only relics of these movements is a gun with the inscription "L'an III de la République Française," now standing in front of the Government Buildings at Qosseir, and one or two wells one of which, the Bir el Inglizi, records the temporary British occupation. During the reigns of Mehemet Ali and Ismail Pasha there commenced a further period of almost feverish activity which brought temporary life and movement, especially affecting the town of Qosseir, whose population increased to 7000, while every nation of importance established consulates, whose arms, now crumbling to pieces over the doors of dismantled houses, attest its former prosperity. A special effort, too, was made to set the petroleum industry of Jebel Zeit and the sulphur mines of Jemsa on a satisfactory basis, and in connection therewith a telegraph line was carried from Qena to Jemsa by way of Wadi Gattar. Of this construction a few poles and wire still remain, especially at the mouth of Wadi Gattar and near Bir Mellaha, but these will probably soon be used up as firewood, etc., by the wandering Arabs. Some years ago Johnson Pasha endeavoured to reopen the Jidami mines, but for some reason unknown to the writers the effort was abandoned, though quite recently they have been re-examined by an expert, and a company has been formed to exploit a large area in the southern portion of the district. Brindley, too, has obtained a concession of the porphyry quarries, but at the time of the writers' visit no work was being undertaken, while a company is endeavouring to place the petroleum wells on a working basis. In the practical remarks there will be occasion to refer to the, probability of success, as far as can be gathered from their observations and to urge the possible commercial importance of the phospate deposits which seem hitherto to have been entirely unrecognized.

This century, too, is conspicuous as marking the first detailed scientific study of this portion of the desert. After the close of the French Expeditions, Caillard, Burton and Wilkinson* (1824) seem to have been the earliest to travel throughout the whole district, the two latter interesting themselves in the natural history and archaeology. Lepsius, too, journeyed from Qena to Jebel Zeit, publishing one of the most valuable works on the Wadi Hammamat inscriptions, and visited the Dokhan mines, where he nearly lost his life through the possession of a bad guide, who did not know the intricate country and the position of the water-holes. But the main explorer of this region is without controversy Dr. G. Schweinfurth, who has enriched every branch of knowledge, having traversed most of the important roads in the desert itself, and either by personal publications, or friendly communications of his facts to others, thrown light on many of its salient features, the botanical results especially standing out by their extreme accuracy and detail. What Schweinfurth did for the desert itself, Dr. Klunzinger has accomplished for the sea-shore, setting the natural history of the present coral reefs of the Red Sea on a secure basis. Many other travellers have explored various portions of this district, Mitchell and Floyer publishing small maps, while the Admiralty has constructed an admirable chart of the Red Sea coast. Yet in spite of all these researches a great part of the Northern Red Sea Hills has only been overlooked, and not examined in close detail. W.F.H.

Section VIII.—METEOROLOGICAL NOTES.

The following remarks on the weather experienced in the desert are of a general character, as no regular system of observations could be adopted. At the same time, temperature was noted almost daily when astronomical observations for latitude were taken in the evening usually between 6 and 7 p.m., and any notable facts with regard to wind, etc., duly observed.

The expedition before starting from Qena camped in the plain outside the town from October 26th to the 29th, the temperature being uniformly high, and local whirlwinds, carrying sand and dust in their train, of constant occurrence.

Apparently change of level affected the temperature, for whereas in Wadi Qena the temperature recorded on October 29th and 30th at about 7 p.m. was 21°·7 C., at the highest camp near Jidami it sank to

* See *Journ. of Royal Geographical Society*, 1832.

16°·1 C., on November 6th, rising again to 18°·9 C., as the lower valleys were entered on the 7th and 8th. On the 10th of November a distinct change took place, the temperature sinking to 15°·3 C., and for the remainder of the month it only once rose above 16° C. The highest evening temperature recorded during November was 20° C., in Wadi Markh on the 1st, the lowest 10° C. at Qena Railway station on the 16th.

In going from Qena to Qosseir, the weather conditions were uniformly pleasant, the variations not being very marked, though the temperature rose soon after the watershed was crossed. A maximum of 16°·4 C., was recorded in Wadi Abu Zeran near Qosseir, and a minimum of 11°·7 C. in the Meeteq range at about 500 metres above sea-level.

On arriving at Qosseir the climatic conditions appeared decidedly unpleasant, though the evening temperatures were if anything lower than those previously noted, varying from 14°·4 to 15°· C. The plain outside the town is exposed to the full action of the wind, dust-storms being of frequent occurrence, and flies a considerable nuisance. If it were not for the beauty of the sea-tints, and the splendour of the sunset colours, Qosseir would possess but few charms for the visitor.

From this point the northern road to El Shayeb was taken, and for the greater part of December the weather was pleasant, 11°·7 C. to 16°·1 being the extremes recorded in the evening. On the 27th, however, there was a marked change in the conditions. On the 26th and the next morning the weather was still fine, but immediately on entering the broad sandy plains at the head of Wadi Safaja, the writers were met by a strong bitterly cold wind blowing from the north-west, the evening temperatures sinking suddenly from 12°·8 on the 26th to 6°·7 on the 27th, and not rising above the latter figure for the remainder of the month. On the 29th and 30th, there were heavy nimbus clouds all day, and on the morning of the 29th (about 6 a.m.) 2° of frost were recorded, the water in the waterbags, etc., being frozen. A few drops of rain fell during the day, much to the disappointment of the Bedawin, who hoped for a heavy storm, the water-pools being in many cases empty. On the 31st there was an improvement, though the weather still remained cold.

Thus the maximum evening record in December was 16°·4 C. on the 6th, and the minimum 6°·1 C. on the 28th, a difference of 10°·3 C.

The first week in January was occupied in traversing from the Red Sea Hills to Qena, the variation being 12°·5 C., maximum in Wadi Gareya on the 5th, and 5°·6 C., minimum on the 4th at the foot of Abu Had, thus it was cool, but unaccompanied by cloud.

The following average gives a résumé of the variations observed :—

Average evening temperatures (about 7 p.m.) :—		
October 29th November 11th, 1897	=18°·7 C.	(12 readings.)
November 12th November 30th, 1897	=14°·1 C.	(11 „)
December...	=13°·0 C.	(20 „)
Divided into {1st half December	=14°·7 C.	(10 „)
Divided into {2nd „ „	=11°·3 C.	(10 „)
1st week January	= 9°·7 C.	(7 „)

The above figures show progressive diminution from October to January, while there were sudden drops on November 10th and December 27th, the latter accompanied by weather disturbances, but no electrical changes were noted.

The remainder of January was spent in Cairo, during which time there was one day of frost and many showers. W.F.H.

Qena-Qosseir Road via El Geita.—Leaving Qena on the 21st November, 1897, where the temperature immediately after sunset varied from 10° to 15° C., the path was followed along the edge of the cultivation. During the journey eastward to Qosseir the weather during the day was always pleasant, but at night and towards morning it was decidedly cool, the temperature at sunrise being below 4° C. in Wadi Hammamat and in Wadi Rieh. On the journey the evening temperature was fairly equable, there being two maxima of 19°·4 C. in Wadi Abu Queh and Wadi Seyala respectively, while the minimum 17°·2 C. occurred n Wadi Sidd and Wadi Rieh on the watershed.

During the first day's march the weather was bright and clear, no clouds being seen. On the second evening there were a few cumulo-stratus clouds and a strong north wind blew. The two following days during the stay at El Geita clouds were observed morning and evening. The following day in the Wadi Um Sellimat was warm and cloudless with no wind; but on the 25th in Wadi Abu Queh some dark purple clouds were seen in the evening. Cirrus clouds were seen in Wadi Hammamat the following day, and in Wadi Sidd on the 27th they were observed morning, afternoon, and evening, the greatest number being noted at sunset. In Wadi Rieh, near the watershed, it was cloudy and windy on the 28th. The Bedawin say that it is always windy at this point on the watershed, and the experience of all the Survey parties bears this out.

Descending the eastern slope of the Red Sea Hills towards Qosseir the day in Wadi Um 'Arat and Wadi Abu Zeran was cloudy, the sun only being seen at intervals. During the two following days the

weather continued the same and until the following morning when the sky cleared and remained so all next day. On reaching Qosseir on the 6th December the weather was not at all pleasant, and during the six days which were spent there the sky remained cloudy, while strong winds blew daily from the north-west, increasing up till midday and then falling. The temperature here was lower than any experienced during the journey across the desert, being on an average 16°·7 C.

On the return journey to Qena by a more northern road (Wadi Safaja, etc.) the temperature remained fairly constant, only varying from 16°·7 C. in Wadi Hamrawein to 17°·8 C. in Wadi Safaja, until the watershed was reached at Wadi Semna when there was a sudden drop to 14°·4 C.

During the journey up the coast-plain heavy white clouds were always visible, and in the evenings the sky was nearly always covered with white fleecy clouds which obscured the stars, and rendered observations for time and latitude a difficult and tedious process. The journey up Wadi Safaja was very pleasant, although the sun at times was hot during the day, and there was an occasional cold wind during the night. It was only after passing the watershed that really cold weather was met with. From this point until Qena was reached on December 30th three most unpleasant days of wind and cold were experienced. At nights the temperature fell to 1° C. and the wind continued without a lull. The sky was covered with black storm-clouds, and in spite of thick clothing the biting wind chilled one through and through.

A fresh start was made from Qena on February 4th, and the evening temperature which on the 5th was only 13° C. rose rapidly to 19° C. on the 6th, and was evidently the precursor of a dust-haze, which on the 8th blotted out every feature of the scenery, 23° C. being recorded at the same time.

During the afternoon the wind veered round from the north-west to the south-west for a short time, and then back again. About 5 p.m. clouds of dust were seen coming from the north-west and soon the atmosphere became loaded with a fine impalpable dust which blotted out the landscape. The canvas on the lee side of the tents was covered with a fine yellow powder, and the air looked as though it had a fog in it. In the evening the wind again veered to the south-west and continued so all the next day, blowing hard and sending clouds of sand rushing along. On the 10th the storm had abated and the hills became sufficiently visible to allow of the work being resumed. T. B.

During the spring months a sudden rise of temperature generally foreshadows a sand-storm of more or less intensity, and is followed by

a clearing of the atmosphere and rapid fall. Thus on the 10th Feb. 13° C. had again been reached, which remained the average till the 19th when there was a sudden rise to 20° C. on entering the Red Sea Hills, and progressive increase to 24° C., this heat period being also accompanied by frequent heat and dust-storms while in camp at Um Disi.

The maximum for February was 24° on the 27th and 28th at Um Disi and in Wadi Atilmi, and minimum 11°·1 C. on the 4th at Qena, a difference of 12°·9 C.

Average for February evening readings, 18° C. (13 readings).

The results for March again indicate the close connection of heat and sand-storm; for after being 21° C. on the 1st in Wadi Atilmi, it fell to 12° C. on the 4th at Um Disi, and then steadily rose again to 20° C. on the 8th, on the 9th ending in a severe sand-storm and dust-haze at the foot of J. Abu Harba. The temperature then again fell, though more slowly, once more reaching 12° C. in Wadi Belih on the 15th, another oscillation upward resulted in clouds, followed by showers when visiting the porphyry mines at Dokhan, while lightning was visible over Sinai.

On the 22nd commenced a rapid rise from 19° C. to 26° C. at Bir Mellaha, where a strong wind blowing down Wadi Mellaha from the north-west, was accompanied by a very severe sandstorm, which came on suddenly during the afternoon, sweeping down the tents and obliterating every feature. The writers had an opportunity of judging how local was the distribution of these storms, for as long as they were in a narrow ravine which traverses the 'Esh range at this point, the weather appeared to be ideal, but on emerging into the longitudinal valley of Mellaha itself, the sand was blowing along in horizontal sheets, and during the height of the storm it was necessary to take shelter behind the bushes which surround the salt-marsh of Bir Mellaha.

The temperature fell next day (27th) to 22° C. and remained at this level to the end of the month. On the day previous to the sand-storm, the thermometer recorded over 37° C. at midday. The maximum evening temperature recorded was 26° C. on the 25th at Bir Mellaha, the minimum 12° C. on the two occasions above-mentioned. March was thus a month of oscillations, each maximum being accompanied by a sand-storm or other atmospheric disturbance.

Evening average for March (23 readings) = 18°·7 C.

April, the last month on which any records were kept, was the most disturbed of any, the 3rd to the 6th being a time of continual change. The notes run as follows: 3rd, clouds; 4th, hot south wind. The whole of this day the shade temperature was over 37° C. On the evening

of the 5th, the wind veered this alteration resulting in a sand-storm at Bir Abu Nakhla which rendered the putting up of tents an impossibility, the sand and gravel sweeping in a continuous stream from the north-west. On the 6th there was still a heavy wind, seriously interfering with the plane-tabling, the temperature, however, had fallen to 18°·5, but rose to 20° C. on the 10th followed by a heavy north-west wind in Wadi Dib. The record fell next day to 18°·5 C., but again rose steadily to 23° C. on the 15th. On the 16th and 17th the traverse up the longitudinal valley running behind Dara was conducted under circumstances of extreme difficulty, plane-tabling being practically impossible on the low passes between the transverse valleys. On the 18th there were strong gales all day, correct mapping being out of the question and these continued to be very frequent during the stay at Ras Gharib lighthouse, after the parties had been recalled for other work.

The recorded evening maximum for April was 26° C. on the 21st and 24th at Gharib lighthouse, and minimum 15° C. on the 17th. This month was therefore especially distinguished by its continual sand-storms in the plains, or heavy winds, mainly from the north-west, in the hills. In the day the temperature in the early part of the month rose above 100° = 37°·8 C. on several occasions.

Recorded evening average for April (15 readings) = 21°·5, probably too low.

There is thus rough evidence of a continual increase from February onward, but occurring in a series of oscillations, the maxima of which are, as stated above, accompanied by atmospheric disturbances, and are followed by a rapid drop in temperature. W.F.H.

Journey from Qena to Jebels Dokhan and Zeit, via Wadi Um Tagher and Sea-coast.—After leaving the other party at Abu Had on February 15th the Wadi Nagateir was followed. Here a temperature of 11°·1 C. was registered, but on entering the Red Sea Hills by Wadi Fatiri, a steady rise of temperature took place, the readings going up from 12°·2 to 19°·4 C.

The weather during the stay in this wadi was rather warm being from 23°·9 to 26°·7 C. in the shade, and 43°·4 to 48°·9 C. in the sun. In the valley there was scarcely any air, but on the hill-tops there was a strong, and sometimes a very cold northerly breeze. On the 21st there was much cirrus cloud in the morning, but with this exception the air was very clear every day except on the 22nd.

During the remainder of the month which was spent going down Wadi Um Tagher the temperature remained fairly constant, the maximum 24°·4 C. being reached by a sudden jump on the 28th. In

this valley the weather was rather warm, but on the hill-tops a cool refreshing breeze was always blowing. On the 24th the wind blew from the north, on the following day from the sea (east); on the 26th there was a light breeze from the west, while on the following day it was almost calm. This changeableness evidently indicated a disturbance of a cyclonic description. Previous to this the wind had been blowing pretty steadily between north and west.

An examination of the evening temperatures taken during the month since leaving Qena showed that from 11°·7 C. at that place on the 5th, there was a sudden jump up to 19°·4 C. on the 6th and 7th as a precursor of a dust-storm on the 8th and 9th, and a sudden drop once more on the 10th to 14°·4 C. with a gradual fall to the minimum 11°·1 in Abu Had and Wadi Nagateir, and from that point a steady rise except on the 25th and 27th to the maximum of 24°·4 C. in Wadi Um Tagher. Thus for the month of February there is a difference of 13°·3 C., and the mean temperature of 17 readings is 16°·1 C.

The month of March began with a maximum reading in Wadi Barud of 23°·9 C. As the sea-plain was entered the temperature gradually fell until it reached 15° C. in Wadi Abu Garia. This was due to the strong north-west wind which blew steadily, increasing to a gale on the 4th with a sand-storm on the sea-coast. These same conditions existed wherever the coast-plain was touched. In the centre of the hills in Wadi Um 'Anab and El Shayeb the temperature again rose; the strong north-west winds died away, but on the hill-tops there was always a pleasant northerly breeze, and the sky was cloudless.

On leaving the hills on the 8th and striking across the plain towards Ras Abu Sha'ar the weather changed. The sky was overcast and there was a dead calm such as precedes a storm. About 11.30 p.m. the storm broke with a fierce gust of wind and sand from the north-west which soon freshened to a gale, hurling masses of sand about in eddies. This continued up to 6 a.m. when it moderated a little, and again became worse about 9 o'clock. Dense masses of sand were carried by the wind, rendering it impossible to keep one's eyes open, but in the afternoon it moderated and finally fell to a calm at night. Again the end of the sand-storm was marked by a sudden fall of temperature, as the following day the reading changed from 19°·4 to 16°·7 C. On the way up Wadi Belih a cold north-west wind blew across the plain but on entering the hills on the 12th it became warmer, the temperature rising to 17°·2 C. in the evening. On the morning of the 13th there was a gale and a bad sandstorm down in the plain, but it was not felt much in the hills; this was again followed by a drop from 17°·2 to 14°·4 C.

in Wadi Um Sidri. On the 18th there were a few light showers of rain accompanied by very cloudy and chilly weather, Jebel Dokhan being enveloped in mist, while on the 19th it was again very cloudy and stormy and there were $2\frac{1}{2}$ hours of light rain after midday, with a few more showers later on. There was a beautiful and stormy sunset in the evening, and at 11 p.m. a very heavy gale sprang up, at times blowing with hurricane force, and levelling the tents; this continued until 3 a.m. and then gradually subsided. On the evening of the 20th sheet-lightning was seen to the south-west. Moving across the plain towards Bir Mellaha there was a gradual rise of temperature but otherwise the weather was pleasant. After leaving Bir Mellaha on the 24th the weather became very oppressive, a close smothering heat prevailing day and night. This continued until the mouth of Wadi 'Esh was reached when the temperature was 23°·9 C. on the evening of the 25th. Next morning there was a light breeze which gradually freshened until at midday it had become a gale, and dense clouds of dust and sand were seen advancing from the north. In the midst of this storm it was practically as dark as night, it being impossible to see two metres in front, while the dust filled the eyes and nostrils, and the sand, driven with tremendous force, stung the face and neck and chafed the skin wherever exposed, leaving a raw smarting surface. In a short time the camels refused to face the storm, so refuge was taken behind a small bush growing on a mound of sand where, lying down and covered with a rug, the end of the storm was awaited. About sunset it moderated and the camp was reached, while in a few hours the air was perfectly free from dust and sand.

From this point on to Jebel Zeit the weather was pretty uniform, and was gradually becoming warmer.

Reviewing the temperatures of March it will be seen that there are two maxima of 23°·9 C., one on the 1st, and the other on the 25th; while there are corresponding minima of 15° and 14° C. respectively on the 4th and 15th. The average temperature for the month out of 20 readings is 19°·56 C.

A glance at the temperatures recorded for this month shows that the weather has had a distinct effect on the thermometer, the approach of sand-storms being clearly indicated by the gradual rise. If it had been possible to reduce the barometer readings at the same time, it would most likely have been shown that the curve was in the opposite direction, viz., on the down-grade. T. B.

Summary.

The following summary briefly gives the main points noted:

1. The temperature diminished from October to January, and then rose continuously, the *maximum* being in April (when records closed) and the *minimum* in the last week of December and beginning of January, frost being noted during this period.

2. *Wind*, mainly from the north-west, was especially prevalent during the months of March and April, and also towards the end of December.

3. The Arabs recognize two areas of maximum cold and wind, viz., Gharib and El Shayeb.

4. *Sand-storms* mark the maxima of the temperature oscillations in the months of February, March and April, and attain their greatest effect in the long valleys and plains which run in the direction of prevalent wind, viz., north-west. In the mountains these sand-storms are commonly replaced by heavy north-west winds, not carrying fine material.

5. The transverse east and west valleys being protected from these winds have a more equable temperature in winter, but become hot and oppressive as the heat increases, owing to lack of currents of air.

6. The sea-coast, being the edge of a comparatively narrow rift, is usually windy, the sea-plains being especially liable to sand-storms and whirlwinds.

7. The district is to a large extent rainless, except at rare intervals, only one shower and a few drops of rain being noted during six months, while electrical disturbances were entirely absent.

Section IX.—BOTANY OF RED SEA HILLS.

Vegetation. As has already been remarked, vegetation is very abundant in the Um Disi region, and in the transverse valleys north of Dara, the most characteristic plant being the thorny crucifer "bsilla," which flowers abundantly in the early months of the year, and is a favourite food for the camels. Wadi el Atrash is in addition filled with big bushes of the long thin branching "markh" (*Leptadenia pyrotechnica*) on which leaves are not generally seen, nor have the flowers been noted by the writers. But most interesting of all is the "moin" or "yessar," (*Moringa arabica* Pers.) which with its graceful birch-like white stem and drooping branches enhances the beauty of many of the wild granite gorges which abound round Um Disi. This tree seems, as far as the Red Sea Hills

are concerned, to be limited to the central Um Disi range, and a few of the valleys round Dokhan and Gharib, while the other principal tree of the district, the "seyal," or spiny *Acacia Seyal* or *tortilis* probably occurs throughout the district wherever conditions are favourable, though mainly limited to igneous regions.

In addition to "markh," the Asclepiads are also represented by the "ghalgai" (*Dæmia tomentosa* L. Vatke), characterized by its peculiar heart-shaped leaves and bitter milky sap. Of third rank as regards size is the wild fig (*Capparis spinosa ægyptiaca*,) whose rounded bright-green leaf bearing a small spine at the tip is very characteristic, while its peppery fruit is much sought after by the Arabs. It bears large many-stamened flowers in early spring. In addition the Capparidaceæ are represented by many small semicircular bushes of *Cleome*, one of them with its drosera-like prickly leaf (*C. droserifolia*, Forsk) being more especially recorded from the neighbourhood of Gharib.

The Resedaceæ too, attain to the size of bushes in the valleys of El Atrash, Um Disi, and Atilmi, the most notable being "gurdi," (*Ochradenus baccatus*, Del.,) though a smaller scentless *Reseda* was also observed in Wadi Atilmi and Wadi 'Esh, near Qosseir, etc. Zilla is also not the only Crucifer noted, as in addition there is a little bushy plant with small white cruciferous flowers most abundant in the valleys round Um Disi, and especially in Wadi el Atrash. This is the "taghr" (*Morettia philaeana* D. C,) and it is probably limited to the Arabian Desert, as it has not been noted in Sinai.

The tamarisks ("tarfa") do not appear to be so abundant in the Red Sea Hills as they are in the more barren plains both east and west of them, but this impression may only be due to the fact that the other and rarer plants were attracting attention at their expense. Zygophyllaceæ (the "bowals," "kusha'id," etc.) too, are of very secondary importance except in barren and stony valleys, where the richer plant-life finds itself unable to thrive. Among the smaller bushy plants in the valleys draining from the granitic hills the composites vie with the crucifers in their abundance. The "kebad" (*Zolikoferia spinosa*, Forsk.) with its strikingly dichotomous spinose branching is abundant in the higher valleys, being with "bsilla," and the aromatic "shia", (*Artemisia judaica*), another composite the commonest of the plants in Wadi Atilmi.

Less striking is the small aromatic pulicaria, "rabl" (rabul); while at the head of Wadi Atilmi a dandelion-like yellow flower is present in small quantity.

Among more local occurrences, a blue prickly borage was found in Wadi Dib; and the large brilliant flowers of the "sakran" (*Hyocyamus*

muticus or *Boveanus*) were common near the Atilmi pass, but Labiates were rare, though a pretty little blue lavender (*Lavendula coronopifolia*), with somewhat long stalk is abundant near the head of Wadi Atilmi. The Urticaceæ are not much represented, but at Bir Hedeba, near Um Disi, a small wild fig tree was growing, named "samyuk" by the Ababda, and probably identical with the "zamiouk" of Klunzinger (*Ficus pseudo-sycomorus* Decn.). The presence of this plant among the desert flora at this locality is here provisionally suggested.

The lilies are represented in the upper part of Wadi Atilmi by a small asphodel (*Asphodelus tenuifolius*, Cav.) carrying but few small white flowers on a long stalk. It has not elsewhere been noted in the Eastern Desert, but was again met with in Eastern Sinai, especially at the foot of Jebel 'Ad el Gharbi, in the south of the peninsula. Um Disi receives its name from the presence of the rushes that surround the pool, the most interesting feature being the presence of the rare sedge *Schœnus nigricans*, which has been only twice previously recorded, in both cases by Schweinfurth, from Wadi Natfeh in the Galala range, and from the oasis of Kharga. Palms in the Red Sea Hills are of remarkably rare occurrence, and where present appear to have been recently planted. In fact, for over 150 kilometres only four groves have been observed, viz. the one at the foot of Jebel Kufra, north of Dokhan (which owes its presence to the industry of an Arab still living), at Bir Abu Sha'ar, at Bir Mellaha, and at Bir Abu Nakhla. The flora of the hills here described would naturally find its closest representative in the granite, etc., hills of Sinai and the country south of the Qena-Qosseir road. The latter has not yet been studied by the Survey, but the collections made in Eastern Sinai enable comparison to be instituted with the latter district.

Principal plants common to Sinai and Red Sea hills.	Plants only noted in Red Sea Hills.	Plants only noted in Sinai.
Zilla myagroides, *Acacia tortilis*, *Capparis* (lassaf). *Ochradenus baccatus* (gurdi). Tamarisks, *Zollikoferia spinosa* (kebad), *Artemisa judiaca*, *etc.* (shia and beitheran), *Pulicaria* (rabl). *Hyoscyamus muticus* (sakran). *Lavendula coronopifolia Asphodelus tenuifolius* (borwag), bulrushes and reeds. *Moringa arabica* was noted in Western Sinai by Barron, but was never met with in Eastern Sinai.	*Dœmia tomentosa* (ghalgai). *Morettia phileana* (tagher) *Ficus pseudosycomorus* (zamyuk). *Leptadenia pyrotechnica* (markh), common in eastern Desert, rare in Sinai.	*Pyrethrum santolinoides* (myrrh). *Otostegia microphylla* (ghassah). *Verbascum.* *Matthiola arabica* (ghomghom). *Anabasis setifera* (hamr). *Iphiona scabra* (zafara, a yellow composite). Palms abundant, rare in Eastern Desert. Number of smaller plants present not noted in Red Sea Hills.

In the above list only the most striking plants are dealt with. It is sufficient, however, to show that the two areas belong to the same botanical province, but that there are some important differences these being in part due to the greater height and larger water-supply obtaining in Sinai, myrrh and "hamr" for instance being almost entirely limited to the summits of the higher hills. As regards abundance, the desert is usually very poor in plants, though Klunzinger states that in favourable years a herbarium of from 100-150 species can soon be brought together, while a total of about 600 have been recorded. In the first estimate the richer desert south of the Qena-Qosseir road is included.

Characteristics of desert flora.

The desert flora above-mentioned has some very striking characteristics which may be noted here.

1.—The abundance of spinose plants is a feature which cannot fail to strike the most casual observer. Every traveller is familiar with the peculiar branching of the zilla and "kebad," so that the bush appears to bristle with spikes in every direction, while the long straight spines of the "seyal" stand in sharp contrast to the short hooks which occur at intervals on the stem of the "lassaf."

2.—When spines are absent many of the smaller plants are covered with prickles, which render their collection somewhat unpleasant. In this respect they resemble the borages of Northern Europe. *Cleome droserifolia* is an excellent example.

3.—Another group of plants is distinguished by its aromatic scent, to it belonging all those artemisias and achilleas which are classed together by the Arabs under the terms "shia" and "beitheran." Here, too, belong the small pulicarias. On the other hand, the mignonettes of Egypt are practically without any smell whatever.

4.—A feature which will strike a European traveller is the fact that many plants are in full flower in the winter months, this being notably the case with the zillas and zollikoferia, while from March to June nearly all of the principal species are at their best.

It will be seen that the principal mountain desert trees belong to the Moringaceæ, Mimosaceæ, and Capparidaceæ, while in the Compositæ, Cruciferæ, Resedaceæ and Asclepiads are included most of those forming large bushes. The Labiatæ, Liliaceæ, and Papilionaceæ are only represented by small plants. As Klunzinger has remarked, the Ranunculaceæ and Orchids, are entirely wanting and the Umbelliferæ are very rare. He further adds that Fungi and Mosses are seldom found. Conifers have never been noted, but Ferns are represented by the maiden-hair at Bir Um Dalfa, it being also found amongst similar hills

in Sinai. In the previous pages, the results obtained during the present survey have been brought together, but those who wish for information on the botany of the desert as a whole should consult the exhaustive summary in the *Mémoires de l'Institut Égyptien*, Tome II., part I., entitled *Illustration de la Flore d'Égypte*, par P. Ascherson et G. Schweinfurth pp. 25-260, and a paper by Dr. Schweinfurth entitled *Pflanzengeographische Skizzen des gesamten Nilgebiets und der Uferlände des Rothen Meeres*, 1869, which is one of the most important distributional papers published on this region.

The first-named work is rendered still more useful owing to the Arabic names for each species being given, while in addition there are constant references to the classical work of Boissier.

In addition to this invaluable paper, the treatises by Forskal and Delile are of value, the plates prepared by the latter being exceptionally fine. The writers have not yet been able to study "Die Vegetation der ægyptisch-arabischen Wüste bei Koseir,"* in which Klunzinger has brought together the observations of many years, while Wilkinson also added a contribution, no copy of which appears to exist in Egypt.

The above notes practically hold good for the whole of the mountain region included in this district, for south of the central massif the country is again poor in species, though individuals of zilla, "kebad," and "seyal" are abundant.

* *Zeits. der Gesell. fur Erdkunde* zu Berlin, XIII (1878), S. 432-462.

Natural Order.	Plant.	Distribution.	Remarks.
1. Menispermaceæ ...	Cocculus Leæba (Sch.)	Trailing on rocks at foot of Abu Harba.	Common climbing plant in Sudan.
2. Cruciferæ	Morettia phileana (tagha) (Sch.)...	Abundant in Wadi el Atrash and near central range at Um Disi, Barud, etc.	Low bush with small white flower. Noted in flower in March.
3. do.	Zilla myagroides (bsilla)	Ubiquitous.	Large prickly bush with pink flowers, valuable camel food.
4. Capparidaceæ ...	Cleome arabica (Sch.)	In flower near Um Disi pool.	Stem straight, bearing pods and bright flowers.
5. do.	Cleome droserifolia...	Abundant north of lat. 27° N.	Low bush, leaves covered with prickles.
6. do.	Capparis spinosa (Sch.)	Common in mountain districts.	Tree growing in rocky ravines, with smooth leaf, peppery fruit eaten by the Arabs, and spines on branches.
7. Resedaceæ	Ochradenus baccatus (gurdi) ...	Common in valleys in and bordering central range.	Large bush.
8. do.	Reseda prunosa (Sch.)	do.	Like ordinary mignonette but without scent.
9. Silenaceæ	Gypsophila Rokejeka (Sch.)	do.	—
10. Paronychiaceæ ...	Robbairea prostrata (Sch.)	—	—
11. Tamariscaceæ ...	Tamarix nilotica (tarfa) (Sch.) ...	Abundant in Wadi Qena and many other localities.	Tree with graceful feathery leaves, etc.
12. Geraniaceæ	Monsonia nivea (Sch.)	Wadi Atilmi.	Small and flat with silvery hairs under leaves.
13. Zygophyllaceæ ...	Fagonia mollis (Sch.)	Both common limestone desert plants.	—
14. do. ...	Fagonia arabica (had) (Sch.)		A very spiky bush.
15. do. ...	Zygophyllum coccineum (bowal) (Sch.)	Abundant in mountain valleys and on Red Sea.	Plant (small bush) with succulent branches & leaves.
16. do. ...	Nitraria retusa (gharqad)	—	Large bush bearing berries.
17. Rhamnaceæ... ...	Zizyphus Spina Christi (sidr) ...	Gives its name to Wadi Um Sidri.	Large fruit-bearing tree.
18. Moringaceæ... ...	Moringa arabica (Moin or Yessar).	Limited to high valleys of central range and Dokhan.	Graceful tree with white birch-like stem and willow-like branching.
19. Papilionaceæ ...	Leobordia lotoides (Sch.)	—	Small creeping plant.
20. do. ...	Lotus arabicus (gadub)....	Abundant near Um Disi pool.	Poisonous leguminose plant.
21. Mimosaceæ	Acacia tortilis (seyal)	Ubiquitous in Red Sea hill higher valleys.	Very spinose tree.
22. do.	Acacia Ehrenbergiana (sellim) ...	do.	do.
23. Cucurbitaceæ ...	Cucumis prophetarum (Sch.) ...	Bir Arras, etc.	Trailing plant.

Natural Order.	Plant.	Distribution.	Remarks.
24. Cucurbitaceæ ...	Citrullus colocynthis (handal) ...	Ubiquitous, especially in Wadi Qena.	Creeping plant, bearing large apple-like fruit containing medicinal liquid.
25. Compositæ	Pulicaria undulata (rabul) (Sch.)	Common in Eastern desert, aromatic plant.	Small plant with marked yellow flowers (March).
26. do.	Francœuria crispa (Sch.)	Valleys of central range.	..
27. do.	Conyza Bovei (Sch.)	do.	—
28. Compositæ	Artemisia judaica (beitheran or shia) (Sch.)	Ubiquitous.	Very aromatic.
29. do.	Echinopus spinosus? (hashir) ...	Especially near Bir Hedeba.	An extremely prickly thistle.
30. do.	Zollikoferia spinosa (kebad)... ...	Abundant in mountains.	Large bush with prickly branching good for camel food.
31. Salvadoraceæ ...	Salvadora persica (arak)	On shores of Red Sea.	Very straggling bush with smooth green leaves.
32. Asclepiadaceæ ...	Dœmia tomentosa (ghalgai) (Sch.)	Abundant south of lat. 27° N.	Plant with heart-shaped leaves and milky sap.
33. do. ...	Leptadenia pyrotechnica (markh).	Very common in Wadi el Atrash and higher valleys.	Bush branching like broom.
34. Borraginaceæ ...	Trichodesma africanum (Sch.) ...	—	Prickly small plant.
35. Solanaceæ	Lycium arabicum	Common.	Large bush.
36. do.	Hyoscyamus Boveanus (sakran) (Sch.)	Common in Wadi Atilmi.	Very bright coloured flower.
37. Verbenaceæ... ...	Avicennia officinalis (shora)... ...	Shores of Red Sea, as near Jemsa.	Large tree growing in salt water.
38. Labiatæ	Lavendula coronopifolia (zeyteh).	Head of Wadi Atilmi.	Blue lavender flower.
39. Salsolaceæ	Salsola fœtida (kharit) (Sch.) ...	In central mountain valley.	Large bush, an excellent camel food.
40. Amarantaceæ ...	Ærua javanica ('arrah) (Sch.) ...	do.	Plant with white fluffy head, like wool.
41. Polygonaceæ ...	Rumex vesicarius? (hamata) ...	do.	Leaf has sorrel-like taste.
42. Euphorbiaceæ ...	Euphorbia granulata (Sch.)	—	Very small plant.
43. do. ...	Crozophora obliqua (Sch.)	—	
44. Urticaceæ	Forskalia tenacissima (Sch.)... ...	—	—
45. do. ...	Ficus Pseudosycomorus (samyuk).	Bir Hedeba.	Wild fig, a tree.
46. Palmæ	Phœnix dactylifera (nakhl)	Kufra, Abu Nakhla.	Date-palm.
47. Liliaceæ	Asphodelus tenuifolius (borwag)...	Abundant in Wadi Atilmi.	Small white flower on stem.
48. Cyperaceæ	Schœnus nigricans (?diss) (Sch.).	Um Disi pool only.	Very rare.
49. Gramineæ	Æluropus repens (Sch.)...	—	—
50. do.	Æluropus mucronatus (Sch.) ...	—	—

W. F. H.

N.B.—Those marked "Sch," have been kindly named from Cooke's collection by Dr Schweinfurth.

Section X.—ZOOLOGICAL NOTES.

No systematic zoological work has been carried out by the Survey, and the following notes which are simply compiled from the observations of previous explorers, embrace such facts as have come under the writer's immediate notice in the course of the expedition. He is indebted to Capt. S. S. Flower, Director of the Zoological Gardens, Giza, for the correct naming of the Mammalia mentioned in the subsequent remarks, and also for several other points of interest regarding their distribution. It is also a subject for deep regret that the late Dr. Anderson, F.R.S., died before he had finished his work on the Egyptian Mammalia, which would no doubt have been a worthy sequel to the fine volume he had already published on the Reptiles of this country.

Mammalia: Leopard, Hyœna. The leopard, still frequently met with in the mountains of Sinai and in the Sudan, is here entirely absent, nor has the writer come across any traces of the hyœna, (*H. striata*), though it is by no means uncommon in the limestone desert to the west, especially in the region adjoining the Nile. **Jackals, Foxes.** Jackals, too, appear to be entirely absent in the hills, and even foxes are but rarely met with, though a young one was brought into camp in Wadi Dara, and a skeleton was found under a rock at Bir Abu Nakhla, while one was also seen by Barron between Jebel Mellaha and Jebel 'Esh. Here again, the contrast is very marked between the limestone hills bordering the Nile and the interior mountain region, foxes being constantly seen making their way across the gravel ridges lying between the river and the Eocene cliff.

Gazelle. If Carnivores are rare, the Ungulates are much better represented, gazelle (Arab, *ghazál*) being reported as especially plentiful in Wadi el Atrash, where several were seen by the Survey, while another was met with on the sea-shore at Jemsa Bay. In Wadi Abu Zeran, near Qosseir, three of these animals were seen feeding off a bush in a small branch wadi; one also was started on the coast plain in Wadi Hamrawein, and another in Wadi Maderaba a tributary of Wadi Safaja, while later, one was seen in Wadi Um Sidri in the plain between the main Red Sea range and Jebel Mellaha. It is most probable that those observed were the Dorcas Gazelle (*Gazella dorcas*, Linn.) which extends through Morocco and Algiers into Egypt, Nubia, and Syria, but it is not yet proved how far the Isabella Gazelle (*Gazella isabella*, Gray) extends to the north, its known habitat being the coastlands of the Red Sea from Suakin to Massowa, and in some districts inland. Capt. Flower states that these species are difficult to distinguish, and many authors

have included both under *G. Dorcas.* The characters of the latter are thus described by Lydekker:* "In this animal the white of the rump does not encroach on the fawn-colour of the haunches, while both sexes have lyrate or sublyrate horns. It stands barely 24 inches at the shoulder, and the horns are relatively long and slender, with their tips incurved, their length being sometimes a little over 13 inches."

African Wild Sheep.

One of the questions of interest raised by Dr. Anderson is, whether the African wild sheep (*Ovis lervia*, Pallas, the name *lervia* of Pallas, 1777, taking precedence of the name of *tragelaphus* of Cuvier, 1817) at present extends within the borders of the district under consideration. Beadnell called the writer's attention to this point, and in consequence a correspondence was opened with some Ababda to whom the whole country is familiar, one of whom, Rean Abid, possesses an exceptional knowledge of the district. The result of these enquiries has been entirely negative as far as Um Disi is concerned, but the "savage rams" are described by them as occurring near Ras Benas, and generally south of the Qena-Qosseir road. Their statement is confirmed by the fact that, although all the important pools in the Um Disi district were visited by the Survey, the only tracks met with were those of ibex, and any others would at once have aroused attention. Speaking in general terms the wild sheep is probably only a rare visitor north of lat. 26° N., though its presence has been recorded as far north as the rocky hills near Minia and in the neighbourhood of the Fayum, on Dr. Schweinfurth's (?) authority.

Ibex.

If the wild sheep be of rare occurrence, it is very certain that the Arabian ibex, Arab. "tetl" (*Capra nubiana*, Cuvier, the name *nubiana* dating from 1825, *sinaitica* from 1828) is common, judging from the abundance of the tracks. Nevertheless, no example was seen during the Survey, and travellers who have had good sport in Sinai seem to have had but little success in the Eastern Desert. According to the Arabs the best locality is round Gharib, but the neighbourhood of Abu Harba and the Jara–Jidami ranges seems also to be much frequented by them, and the Central Massif is obviously a region well suited to their habits, water being abundant, and the slopes steep. "This species is distinguished from the Himalayan ibex by the horns being more compressed, and having the knobs on the front surface arranged at regular intervals."

Wild Ass.

It has also been asserted that the wild ass has been seen at Um Disi, notably by Burton, but the writer's enquiries give the same result as for

* Lydekker, R., *Royal Natural History*, Vol. V., pp. 292 and 293.

the sheep, viz., that the wild ass is unknown beyond the Qena-Qosseir road, though fairly common south of it.

Another animal about which enquiry has been made is the hyrax, Arab. "wobur" (*Procavia*, this generic name being prior to that of the better known *hyrax*) as it is of importance to know what are the precise affinities of the Egyptian variety, which has been stated by Dr. Schweinfurth to be present in Wadi Sheitun, on the western side of the limestone desert between Qena and Assiut. This little animal has, however, a variable distribution, this being dependent to a large extent upon the amount of rainfall, so that a colony may completely disappear from a district after a dry season. The hyrax were in large numbers in a small valley near Bir Inglizi, on the Qena-Qosseir road (their existence at Sheitun was unknown to the Arabs of whom the enquiries were made), but in the igneous hills, at any rate, they do not extend far north of the Qena-Qosseir road. Capt. Flower informs the writer that two specimens from the Emerald Mines in the desert of Etbai were presented on the 25th May, 1900, to the Giza Zoological Gardens by Dr. Grote, who refers them to the species *Burtoni*. Hyrax.

As the Egyptian type has not been personally observed no detailed description can be given, but all the species agree "in having sharply pointed muzzles and small rounded ears, while their bodies are covered with a thick coat of nearly uniformly-coloured hair (deep-brown in those obtained by Skill in Sinai), varying in length in different species." In Sinai, too, they, as described by Dr. Blanford, "live in rocky or stony places, in communities, like rabbits, haunting holes beneath the rocks. A large pile of loose blocks, especially if there are precipices around, is sure to be inhabited by them. They are frequently found, too, in rocky water-courses." Though usually retiring at midday, a number of them were seen running among the rocks at that hour in Wadi Hebran. Their feet are of remarkable structure, being very flat, and pad-like, so that they can run with ease on the smooth granite slopes. The toes are rather leathery in appearance, there being four on the front and three on the hind feet. The presence of the two pairs of well-marked front teeth, one in the upper and the other in the lower jaw, also give a characteristic appearance which enables the skull of a hyrax to be readily recognized.

As regards the larger Mammalia, therefore, it may be generally stated that, apart from some possible isolated colonies, they are but rarely present north of the Qena-Qosseir road or far east of the Nile, with the exception of the gazelles and ibex, which appear to be ubiquitous in their distribution.

Rodents Jerboa.

The rodents are well represented, the holes of the small sandy-grey three-toed jerboas being everywhere abundant. Nevertheless, these little animals themselves are not often seen, but at nightfall become very active, and appear to possess curiosity developed in a high degree. Thus one evening when the writer was sitting on a hillock near the camp at Qosseir, a jerboa came up, and leapt round in a series of wide circles, but on the slightest movement at once made off. On several occasions they entered the tents at night and jumped about over the sleepers, but were far too quick in their movements to be caught. At Um Disi one made persistent endeavours to dig into the tent under the flaps, desisting when the latter were sharply tapped, only to begin again a few seconds later. At the foot of J. Guereb, two of the Arabs brought in a small specimen on a very cold and windy day. On being taken out and put under one of the bsilla bushes, it had evidently formed the impression from the warmth of the tent and its good reception that it had fallen among friends, for it jumped back to the tent, and, arriving there, curled itself under the blankets.

Probably of frequent association with the above is the allied jerbil, which, however, has not been especially noted.

Hare.

Hares (Arab. "arnab") have been seen, one being disturbed among the "bowal" bushes in Wadi Abu Had, while another was noted near Qosseir, but they have also been observed by the writer in the desert east of Heluan and Cairo. The Egyptian hare is stated to be smaller than the common species, but with relatively longer ears and paler fur*.

Thus bringing together the facts collected about the Mammalia during the Survey expeditions, the following generalized table is obtained:—

Common to Eastern Desert and Sinai.	Found normally south of Qena-Qosseir road only.	Sinai.
Capra Nubiana (ibex).	*Ovis Cervia.*	*Felis pardus.*
Gazella, prob. *dorcas.*	*Equus asinus.*	*Capra nubiana.*
„ (gazelle).	Hyrax (*Procavia sp.*)	*Gazella*, prob. *dorcas.*
Hyæna striata, near Nile.	The latter may possibly be abundant north of lat. 26° N. during rainy seasons.	*Procavia syriaca.*
Jackals.		*Hyæna striata.*
Foxes.		Jerboas.
Jerboas.		Jerbils.
Hare.		Hare.
		Hedgehog.

Raven.

Birds.—While no systematic collection of skins has been made, it was impossible to pass through the desert without being struck by the

* Lydekker, *loc. cit.*, Vol. III., p. 197.

abundance of the birds, even in the most out-of-the-way districts. Any specific names mentioned are on the authority of previous writers on this district. Of birds seen the ravens are especially characteristic. According to Dr. Heuglin these birds (Arab. "*ghorab*") belong to two species, the short-tailed raven (*Corvus affinis*), and *Corvus umbrinus*, the large deep-black variety. Their distribution in this region is only limited in one direction, viz., they are never found far from water, and their presence at any spot may be taken as an indication of its proximity. Of totally different habits, but extremely abundant in all the great valleys, are the desert-larks (*Alœmon desertorum*) with their characteristic grey plumage, long slender beak, and rapid run; while almost equally common are smaller varieties, probably the finch-lark, of which one, *Ammomanes deserti*, with a short thick beak, is readily recognized by the peculiar and sudden manner in which it drops to the ground. Klunzinger also mentions *Calendrites macroptera* as being a characteristic desert-lark. Another bird which appears to be very common is a wagtail which has been referred to the African species *Motacilla vidua*. **Larks.**

One of the most widely distributed of desert birds is a small chat which at once catches the eye by the sharp contrast in its plumage, black and white being irregularly distributed. Klunzinger mentions two species *Saxicola leucocephala* and *S. isabellina* as characteristic. **Chats.**

Towards the spring, and especially about April, swallows were flitting in all directions, in the neighbourhood of Dara, being at once recognizable by the beautiful purplish-blue upper plumage and long outer tail-feathers. Presumably they were preparing for migration to Europe, as they appeared most abundantly in the first week of April. **Swallows.**

Owls, too, are of frequent occurrence, judging from their cry at night, though during the traverses none of these birds were actually seen. Heuglin states that the two commonest types are the eagle-owl (*Bubo ascalaphus*) and the church-owl (*Athene noctua*), while in addition night-jars have also been met with. **Owls.**

Of the birds of prey the vultures are those most commonly observed, the most frequent being (according to Klunzinger) the carrion vulture, (*Neophron percnopterus*), the well-known "rakham" of the Arabs. Numbers of these huge birds can be seen slowly circling over any spot where a dead camel is lying, and in some cases they appear to follow human beings also for long distances, probably in the hopes of picking up stray scraps of food. **Vulture.**

In the picturesque little gorge, full of reeds and rushes, by which Wadi Mellaha has cut its way to the sea, the rocky cliffs are crowded

with the nests of some species of fish-hawks, possibly the osprey. To any one who may be able to visit the spot and test this point, a note given the writer by Capt. Flower may prove useful, viz., that the osprey (*Pandion halietus*) differs from the eagles, hawk, etc., in having the outer toe reversible, and also having no aftershaft to the contour feathers.

During the earlier part of March, while camped in Wadi el Atrash, great flocks of heron-like birds crossed over the valley, going north-east in the direction of the Sinai Peninsula, hundreds of birds flying together. Similar assemblages were met with near Bir Mellaha, and were common on the shores of Jemsa Bay, while subsequently a large body was seen crossing from Ras Gharib lighthouse to the Sinai coast north of El Tor, the birds flying close to the water. The Arabs stated that these birds were returning from the Nile Valley, and they are therefore presumably the same as the white-plumaged herons or egrets which are found so abundantly after the inundation in the fields bordering the Nile, or in the Fayum.

A common bird in the Wadi Qena, immediately outside the cultivation, is the sand-grouse, whose peculiar cry can often be heard in the early morning, though it itself is rarely seen. In the desert at a distance from the Nile they are only met with in the neighbourhood of water, Barron recording several cases on the Qena-Qosseir road, near El Geita, etc.

Partridges. Partridges, on the contrary, occur more commonly in the central hills of the Red Sea, especially in the massif near Um Disi. When going up to the Atilmi pass, two of these birds were put up, their red legs being the most conspicuous feature. While going down Wadi Belih, they could frequently be heard calling, though owing to their protective colouring, they themselves were practically invisible. The usual species is *Ammoperdix Heyi*. The common quail (probably *Coturnix communis*) may occasionally be met with, one having been put up in Wadi Abu Had, but obviously, with abundance of food in the Nile Valley, there is not much attraction for these birds in the comparatively sterile desert regions. Naturally, on the shores of the Red Sea, sea-birds are numerous and varied, especially gulls, but no special notes have been kept of their habits.

Reptiles.—Fortunately the reptiles of Egypt have received special attention at the hands of the late Dr. Anderson, whose fine work is illustrated by excellent coloured plates and photographs. The following are brief notes of the writer's observations as to their occurrence and habits.

The geckos are not infrequent, especially the lobe-footed form, (*Ptyodactylus lobatus*), which is often seen on the rocky sides of the cliffs, especially in moist places. *Stenodactylus* is also mentioned by Klunzinger. **Lizards.**

The agamas are also represented by the peculiar flat-bodied, large-headed, uncouth-looking little agama (*A. pallida*, using the somewhat vague specific name), which appears to live principally in the open air, and does not burrow in the ground like other lizards.

But most striking of all are the spiny-tailed lizards (*Uromastix*), at once recognized by their characteristic spinose tail, which are by no means uncommon in the Red Sea Hills. They seem chiefly to live on the soft parts (leaves, legumes, etc.) of the "seyal," and are perfectly harmless, one of them, caught alive a little north of Dokhan, allowing itself to be taken in the hand without making any resistance. Apparently it lives chiefly in the clefts of the rocks. Apart from the above, the commonest lizards are species of the fringe-toed *Acanthodactylus*, which are found everywhere in the more fertile valleys when the sun is shining brightly, *Eremias* also being very common.

Snakes are especially abundant in the hills extending from Dokhan to Abu Marua, the most noticeable being the "kakar" or horned viper, (*Cerastes cornutus*), which is evidently much dreaded by the Arabs, as owing to its indefinite colouring it is not easily observed. One of the Arabs nearly trod on one which was sleeping under a "seyal" tree at the foot of Abu Harba before he realized his danger. Barron also records numerous occurrences. One was caught in Wadi Belih with a bird in its mouth which it had just killed, a second attacked one of the party in Jebel Mellaha as he was walking up a small wadi, but escaped into a hole in the rock, a third was killed at Bir Abu Nakhla, while a fourth of somewhat different appearence was slain after a fight on the coast plain near Jemsa Bay, having the remains of a wagtail in its stomach. In Wadi el Atrash, a grey snake called "asella" by the Arabs, but stated by them not to be dangerous, was also observed resting on a stone, The neighbourhood of Dokhan is especially notable for the abundance of its snakes, which lie in wait in the "bsilla" bushes for the small birds, which are common in these valleys, and appear to form their principal food.

The only other species noted was met with in Wadi Dib, having a broad yellow band down its back, in this respect resembling *Psammophis shokari*.

Amphibia and fish, for obvious reasons, are not known from the desert itself.

PART II.

GEOLOGY.

INTRODUCTION.

This part deals with the country examined by the two parties working in the Eastern Desert during the season of 1897-98, and will show how far the knowledge of the district has been advanced in consequence of these expeditions, but a preliminary statement may first be made as to the broad features of the district and the order of sequence which will be followed in considering details, notice of previous work forming the introduction to each separate division, except in the case of papers received since this memoir was in manuscript, which will be found at the end of the sections to which they belong.

The order of description is as follows :—

I.—Pleistocene :—
- *a.*—Igneous Gravels and Conglomerate with Newer Beach Deposits.
- *b.*—Older Beach Deposits.
- *c.*—Coral Reef.

II.—Pliocene: Valley Limestones and Conglomerates.
III.—Miocene Beds.
IV.—Eocene Limestones and Shales.
V.—Cretaceous Limestones.
VI.—Gypseous Beds.
VII.—Nubian Shales and Sandstones.
VIII.—Folds and Faults.
IX.—Igneous and Metamorphic Rocks.
X.—Practical Notes.
XI.—Petroleum.
XII.—Influences giving rise to the Eastern Desert structure.

General Statement.

Relation of Igneous Gravels to Valley Deposits.

I.—At the commencement of the Geological Survey an interesting series of gravels, conglomerates, and gritty limestones was met with in the Nile Valley between Qena and Esna, the latter being found to contain several species of foraminifera, which have been described by Chapman*, and were considered as proving the marine origin of

* *Geol. Mag.*, No. 423, N. S., Dec. IV., Vol. VII., No. 1, January, 1900, p. 14-17.

these beds. This view has been disputed by Dr. Blanckenhorn (see p. 156) who considers that the foraminifera might have been derived from the Eocene beds of the neighbourhood. Further detailed examination has shown that the gravels can be divided into two categories, an older, consisting entirely of limestone and chert, intimately connected with the marine limestone, and a younger, formed of igneous and metamorphic pebbles, unconformable to the former beds and representing an entirely different set of conditions.

Plateau Gravels and Coral Reefs. Near the shores of the Red Sea the igneous gravels again appear in the neighbourhood of Qosseir, containing Pleistocene corals, or underlying thin beds of limestones in which these fossils occur.

Miocene beds. II.—From the palæontological evidence (especially in connection with the sea-urchins and oysters) it is certain that Miocene beds are present between the Gulf of Suez and the Red Sea Hills, but their study is rendered difficult owing to their being widely overlaid by the Pleistocene gravels.

Eocene rocks. III.—The Eocene rocks will form a fourth division, and their relations have been examined in some detail. These will be included under the head "Eocene Limestones and Shales." The result of the present survey has been to materially extend the range and importance of these beds on the eastern side of the Red Sea Hills. The Duwi range, near Qosseir, and many of the isolated limestone hills lying between the main range and the sea are now shown to be of Eocene age, while similar strata form the major portion of the Mellaha limestone ridge, running parallel to the Red Sea south-west of Jebel Zeit. Special stress must be laid on the Esna Shales and limestones at the base of the Eocene, as it is probable that the resemblance of these to Cretaceous beds of similar lithological character has led some excellent observers into error regarding the age of strata further south.

Cretaceous rocks. IV.—Beds of Cretaceous age, including Ptychoceras limestones, phosphate beds, etc., were discovered by the Survey to the west of Qena, and with the key thus provided, these have been mapped in the Duwi hills near Qosseir, in several faulted synclines on the borders of the Red Sea, and in the Mellaha limestone range. The most interesting feature resulting from this discovery is the dissimilarity existing between the Cretaceous beds in this area and those described by Zittel from Schweinfurth's work in Wadi Araba and the Galala hills, the Hammama and Duwi Cretaceous beds (as they may provisionally be termed), differing in essential particulars from the Araba type, which is closely connected with the Sinai and Abu Roash facies. Not only is this the case, but the Hammama and Duwi limestones, show marked dif-

ferences between themselves, which will be subsequently described. The existence of Upper Cretaceous beds near Qosseir and Jebel Zeit had not however escaped the notice of Dr. Klunzinger, in whose collections Prof. Zittel recognized *Nautilus desertorum*, Zitt. *Roudairia* sp., *Gryphaea vesicularis*, and *Ostrea barrandei*, etc.

V.—Another point of geological importance, which is strikingly shown in the hills to the east of Qena, is the existence of a very distinct unconformity between the Cretaceous and Tertiary beds a fact which agrees with the results arrived at by Beadnell while studying the western oases.

VI.—As a result of the recognition of the Cretaceous in this area, the Nubian Sandstones and Shales which underlie the Cretaceous limestones have been definitely shown to be not later than Cretaceous in age,* and, as Blanckenhorn has provisionally determined the fossils obtained as Campanian, it is probable, in view of the perfect conformity between the Nubian Sandstones and the overlying limestones that part of the former is Senonian, indeed oysters of Santonien age have been found in the sandstone to the east of Bir el Geita.

The base of the Nubian, where it meets the igneous rocks, has also been carefully examined, with the result that the opinion, (expressed by Floyer and others), that the granite has intruded into the sandstone, is considered untenable, the sandstone lying on a smoothed-down surface of igneous rock. It may be stated, however, that while in Western and Eastern Sinai the same statement holds good as a general rule, in the former area Barron has noted intrusions into the Nubian Sandstone of Carboniferous age, and other intrusions of a later age will be described further on.

VII.—The igneous and metamorphic rocks have presented a very wide field of research, and an effort has been made to ascertain the relative ages of the principal component members. The general result has been to prove the metamorphic series the older, while the gneissose granite intruded into it has been veined through and through by dykes of quartz-felsite, diabase, etc. A pink granite, and the red granite which forms many of the boldest of the Red Sea Hills are probably the youngest of all except the dyke rocks, and as has been stated, but few of the igneous rocks are apparently younger than the Nubian Sandstones.

VIII.—Since the Red Sea and Gulf of Aqaba have been shown to be part of great Rift systems, the effect of tectonic changes on the

* See Fraas, *Geognostiches Profil vom Nil, zum Rothen Meer.* Zeitsch. der Deutsch. Geologischen Gesellschaft. Bd. 52, Heft. 4, 1900, p. 11.

character of the Arabian desert has been referred to in several works, especial stress being laid on the importance of faults in the production of the lower chains (J. Mellaha, 'Esh and Zeit) parallel to the main Red Sea Hills. In this memoir the knowledge of these changes will be amplified, as Wadi Qena is here shown to be bounded by faults, while the outliers of Abu Had and Serrai equally owe their origin to dislocation. On the eastern side towards the Red Sea, faults have been developed on a great scale, the limestone ridges scattered among the igneous hills owing their preservation to the existence of these fractures. Thus strike-faulting on a grand scale has been proved in the Duwi range, Tertiary strata being brought in succession against Nubian Sandstone, granite, and schistose diabase, while further north the sedimentary beds form outliers bounded on every side by fault-planes.

This strike-faulting has been also especially observed by E. Fraas.

IX.—The practical questions connected with the desert regions have naturally been kept in mind by the Survey, the existence of gold and the nature of the petroleum supply having both received attention, but as these points are once more being practically tested by syndicates or private individuals, no special stress need be laid here on the results in these preliminary remarks. A fact that has come out very strikingly is the important part played by iron ores in this region. In the metamorphic districts the compass becomes practically useless, owing to the abundance of magnetite in the basic rocks, while in some localities the ore has been segregated, or still more frequently carried up in quartz veins, and appears to have been extensively worked by the Romans. Thus in areas so widely separated as Wadi Dib (near Jebel Mongul) and Wadi Abu Jerida (near J. 'Aradia) hæmatitic iron ore has been found in abundance, containing from 75 to over 82 % of iron oxide yielding over 57·5 % of metallic iron, while iron ores of various grades are present in other localities. It is possible that closer search may show the existence of copper ore in the neighbourhood of Jebel Dara, as hydrous silicates of that element are frequent; but the Red Sea Hills are undoubtedly most famous for the variety and beauty of the ornamental building stones, which under the economic conditions then prevailing were successfully worked by the Romans. Foremost among these is the Imperial Red Porphyry of Dokhan, but good porphyry is now also shown to exist far north of the typical locality, while attention is again called to its presence in Jebel 'Esh, east of Dokhan. Some of the diorites or gabbros, such as those at Wadi Semna or at J. Mons Claudianus, and the pink granite at the mouth of W. Foakhir,

have also been much quarried in previous centuries, while the working of the serpentines and sandstones, especially the black felspathic sandstone in Wadi Atolla and eastward, dates from early Egyptian times. Marble has also been noted in the upper part of Wadi Dib. Especial stress, too, must be laid on the existence of phosphate-bands over considerable areas, and these will be more fully dealt with when all the analyses have been completed, samples having at present yielded 40 to 50 % of tricalcic phosphate. From their position and distribution it is possible that these beds may become of considerable local value. It may be here stated generally, that they almost everywhere accompany and underlie the Cretaceous limestones wherever these are developed.

GENERAL GEOLOGY OF THE DISTRICT.

On the western side of the Red Sea Hills the geological arrangement is comparatively simple, the following being the succession from east to west:—

(1) Igneous and metamorphic rocks;
(2) Nubian Sandstone;
(3) Cretaceous limestones;
(4) Esna shales, marls and limestones;
(5) Eocene limestones;

and in spite of minor changes due to faulting, these beds trend in a north-west and south-east direction. The sequence appears for a time to become simpler as the rocks are traced northwards, until, opposite the mouth of Wadi Gurdi, only a broad plain lies between the Eocene and Igneous ranges. Still further north, judging from Zittel's map, the succession must again become more complicated, as a distinct band of Nubian Sandstone is shown lying west of the Red Sea Hills.

To the south-west of the district near Qena, the plateau-gravels and limestones fill up the spaces between the faulted outliers and the main plateau.

To the north of latitude 27° N., on the eastern side of the Red Sea Hills, there is again the north-westward parallelism noted above, but in addition a repetition comes in, which has been directly ascribed to faulting. Thus in addition to the main igneous range, two lower ones of similar geological structure rise in succession to the east, viz., Jebel 'Esh and Jebel Zeit. In the first of these the general succession is similar to that noted on the western side, and the topographical features produced are of the same nature, but chemical alteration of

some of the beds has given Jebel Zeit a different aspect, to be referred to later. These ranges are practically parallel to the direction of the Gulf of Suez, and Jebel 'Esh is bounded for most of its length by a tilted coral-reef, which in many cases forms summits higher than the main ridge. South of latitude 27° N., the structure of the eastern side is far more complicated, the faults to which the complexity is due, not being in all cases parallel to the general trend of the Red Sea, but on the contrary, frequently very oblique to that direction. The country thus becomes a maze of low metamorphic hills, steep granite ridges, deep-brown bluffs of Nubian Sandstone, and long ranges or isolated outliers of Eocene and Cretaceous limestones, sometimes synclines broken on all sides by faults, and at others, hills whose strata instead of being almost horizontal, are dipping at steep angles.

The central Red Sea Hills themselves are broadly differentiated into four types:—

(1) A metamorphic and basic series;
(2) A gneissose granite;
(3) A pink granite;
(4) A coarse granite type.

Nos. 1, 3 and 4 play the greater part in the construction of the Red Sea Hills, the porphyries, dolerites, etc. of No. 1 forming a long series of hills extending northward from J. Dokhan to the west of J. Dara, which is flanked by the bolder granitic ranges of Abu Harba, Miusulman, Dara and Gharib, composed of the coarse granite. On both sides of these higher crests the gneissose granite forms low hills, and weathering faster than the parallel dykes of felsite, etc., which penetrate it, gives rise to a peculiar type of scenery—a number of parallel low ridges rising out of sandy plains or valleys.

South of latitude 27° N., the conditions are different, the metamorphic rocks of more basic character no longer forming mountain chains, but low hills (not more than 200 metres above the valleys) which have the most complex windings, and out of which rise ranges of red granite as described in the topographical part. As we approach latitude 26° N., the metamorphic rocks become of increasing importance, and finally the higher crests, such as those of Meeteq, are no longer granites, but gneisses, while the lower hills are almost entirely composed of sheared diabases, slates, dolerite, etc.

With these preliminary remarks, attention may now be turned to the details connected with the highest or most recent beds, viz:—

Section I.—PLEISTOCENE.

Sub-Section a.—Igneous Gravels and Newer Beach.—These occur along the edge of the cultivation as far as Gebalaw on the road to Bir Ambar from Qena, where they are found capping the mounds of marly clay which are 17 to 18 metres above the cultivation, and end in an abrupt scarp. These gravels have evidently come down the Wadi Qena, and spread out in a fan-shaped delta-like deposit as the wadi opens into the Nile Valley. They form the floor of the Wadi Qena, and were found in a digging for water near Qena at a depth of 5·86 metres, where they were mixed with limestone pebbles. This bed was traced into the town, and it very probably persists under the alluvium right across the Nile Valley, since mounds largely composed of igneous pebbles have been found by Beadnell* on the western side, forming the surface of the plain between the cultivation and the Eocene cliffs, leading him to the conclusion that these gravels had been deposited over the area (being derived from Wadi Qena) before the existence of the river. The northern edge of this fan was found to behave in the same way as that on the south.

These gravels are next met with on the sides of Wadi el Qurn, where they form small steep-sided hills. Here the junction between them and the Pliocene Marls is very well marked, and their boundary can be traced a long distance by eye, owing to the marked difference in colour.

The pebbles composing them are not of great size, measuring about eight centimetres by four. They represent a very diverse series of rocks—granite, gneiss, diabase, andesite, rhyolite, quartz-felsite, grauwacke, (probably an ash), conglomerate, and ferruginous sandstone.

Igneous pebbles also occur up Wadi Matula; and round the village of El Geita mounds of the same are met with, while from this point far into the igneous range these gravels are found in the wadis. There are four main hill systems from which the gravels noted in this district south of latitude 27° N. have been derived, viz.:—

1. Jarra-Jidami range.
2. Meeteq range.
3. Jebel Um Marwat and Jebel Abu Garahish.
4. Fatiri district.

1. *Jarra-Jidami range.*—Near the centre of the district, at the foot of the granite range of Jebel Jarra, is a fine-grained sandstone crowded

* ("Note on the Geology of the Nile Valley," *Geol. Mag.*, July, 1884, p. 289.) Also noted by Newbold and Dawson.

with angular pieces of the igneous rocks of the neighbourhood, forming low terraces, probably the result of local downwash.

In Wadi Jidami, which drains this district, the gravels occur in the bends, capping low mounds of Nubian Sandstone, as far as the mouth of Wadi Hammama.

In Wadi Sellimat, (the narrow valley running from Jebel Jidami to Wadi Hammama,) these were again well displayed, forming terraces over 2 metres thick; while where Wadi Hammama widens into a plain, the gravels were about 6 metres thick, the principal components in these (as in the above cases) being dolerite, quartz-felsite, and hornblende-granite, the largest fragment measuring ·06 × ·03 × ·03 metre.

2. *Meeteq.*—Igneous gravels were again seen at the foot of Jebel Meeteq, composed of the local metamorphic rocks, and over 1·5 metres in thickness. These are only of local distribution in the side-valleys of the range.

3. *Jebel Um Marwat and Jebel Abu Garahish.*—Gravel ridges, composed of basic rocks, are frequent in the tortuous Wadi Waera and almost fill the wide expansion of Wadi Saga west of the Duwi range. Similar ridges, 2 metres thick, are present on the northern side of the opening of the Wadi Saga gorge, near its junction with Wadi Sodmein.

4. *Fatiri District.*—While the southern end of the Nagateir plain is entirely composed of Nubian Sandstone, to the north of the drainage-line leading down from Wadi Fatiri there are the remains of what appears to have been an extensive gravel plateau, subsequently much reduced by denudation. Underlying this gravel, which is composed of granite, quartz-felsite, dolerite and whetstone, is a coarse sandy grit, evidently composed of quartz derived from granite. This rock is very friable, and has not yet become properly cemented together. In this region these gravels rest unconformably on Nubian Sandstone and the whetstone rock of the district. There are in addition to the above gravels, a number of others locally distributed in the great plains and hills west of the central watershed.

Though north of latitude 27°, the gravels on the western side of the watershed are not so conspicuous, yet in the central range (Um Disi-Gattar) terraces of igneous rock-fragments are not infrequent, one some 3 metres thick forming a small plateau on which the camps are usually pitched at Um Disi, and terminating in a low vertical cliff (consisting of igneous pebbles embedded in a sandy matrix) at the point where the small wadi running down from Um Disi pool enters the main valley. On going up Wadi Atilmi and the other interior valleys, there are also numerous terraces of igneous pebbles, which block the mouths of some of the side wadis.

Gravels on the Eastern Side of the Watershed.

1. *Wadi Abu Zeran to Qosseir.*—Opposite the wells of Beida, travertine over 6 metres thick is seen resting on a breccia of the local rocks cemented by calcareous material, while near Ambagé the gravels assume topographical importance, forming a well-marked plateau down to the shores of the Red Sea. The present stream is depositing travertine, and in places has cemented together the chloritic and other schistose rocks of the district, the whole resting on the upturned edges of the Tertiaries. The succession from the top is:—

1. Large pebbles cemented by travertine.
2. Finer sandy rock.
3. Travertine, with boulders over 60 millimetres diameter.

It is impossible to state at present whether the whole of the valley gravels present here originate in the same manner, but it was interesting to find that in the torrent beds descending from the diabasic hills which bound the narrow ravine of Abu Zeran, the rock-fragments have been also cemented together, giving rise to a compact conglomerate. That calcareous material sufficient to cause this feature should be present in such quantity in an igneous region is probably due to calcareous alteration in the diabases. (T.B. and W.F.H.).

In a precipice at the head of a small valley near Ambagé, the following succession was noted:—

Top:

1. Siliceous limestone.
2. Coarse gritty sandstone.
3. Hard bed of crystalline limestone looking dolomitic.
4. Bed of conglomerate of rounded siliceous pebbles, and containing pieces of black iron ore. Thickness, 9 metres.
5. Coarse gritty sandstone.

Gravels of Coast Plain.

Along the Coast Plain gravels occur at the following places: — On the top of the low plateau sloping upwards towards the igneous hills to the north and west of Qosseir, igneous pebbles form the highest bed, mixed with numerous specimens of coral, and spines of echinoderms; while nearer the sea many shells of *Tridacna*, *Murex*, etc., are found embedded in the calcareous matter. This deposit slopes up toward the boundary of the beach deposits, gradually losing all its fossils, and finally ends in an abrupt escarpment, composed of gypsum at the base and beach deposits at the top, at an elevation of 70 metres above the sea. Stray pebbles are found lying on the top of the higher gypsum hills, pointing to the conclusion that this deposit had a greater extension in earlier times.

In Wadi Hamrawein, where this valley debouches from the igneous range, there is another bed of these pebbles capping a beach deposit and lying 95 metres above the sea. This continues down either side of the wadi until it merges into the plain, when it forms the surface as at Qosseir.

Similar deposits occur in Wadis Abu Hamra, Sodmein, Saga, Abu Shigeli, Queh, Salem, Jasus, and up to Safaja where the plain narrows almost to nothing. The latter, except where it is occupied by low knolls of coral limestone or gypsum, is covered with these gravels.

At the mouth of Wadi Salem the deposits assume a more calcareous character, the igneous pebbles becoming comparatively less important. From this bed numerous spines of echinids, fungidæ, various gastropoda, and pelecypoda were collected.

Near Wadi Abu Shigeli, in the gritty limestone forming the newer beach, numerous echinoderms of a flat type (*Laganum depressum*) were obtained. This deposit was laid round the foot of a hill of the older beach in an unconformable manner.

Corals in gravels.

At Wadi Queh these beds contain many corals and form a low ridge 24·4 metres above sea level. Associated with these are small coral-reefs, 18 to 24 metres above sea level, containing corals, echinoderms of a flat type, *Pectens* and other pelecypoda, *Cerithiidæ*, *Nassidæ*, *Neritidæ*, and various members of the *Fusidæ*, *Conidæ*, *Cypræidæ*, *Olividæ*, as well as numerous spines of echinoderms of different species (For specific determination see List, p. 141 and seq.).

The confluence of Wadi Safaja and Wadi Wasif.

Wadi Safaja.—In Wadi Safaja, near the boundary of the igneous range, this deposit is also present, lying on and against the Nubian Sandstone. It is composed of the following members, beginning from above:—

Top.

1. Conglomerate of igneous pebbles.
2. Gritty limestone containing corals, etc.
3. Conglomerate of igneous pebbles.

Base.

These were continued round the edge of the sandstone, and were laid on to the flanks of the granite in the form of a coarse conglomerate of igneous pebbles, some of which were 15 centimetres in diameter.

*Wadi Safaja and Wadi Wasif.**—In the syncline at this point occurs a formation consisting of the following members, beginning from above:—

Top.

1. Flinty conglomerate, similar to No. 3.
2. Red gritty sandstone containing occasional layers of pebbles. Thickness, 9 metres.
3. An angular conglomerate formed of flints derived from the flint-bearing beds of the Eocene.

Base.

The total thickness of the beds is 46 metres.

*Plate IV.

The red sandstone, where it is exposed to the action of the atmosphere, weathers out into small round balls, varying from the size of a pistol-bullet to that of a walnut, these also being frequently aggregated into grape-like bunches. This peculiar structure may be due to the originally concentric deposition of calcareous and sandy matter, from which the outer shells of the cementing carbonate have been removed, owing to their more feeble resistance to weathering. These strata lie unconformably on the Eocene limestone, dipping at angles varying from 10° to 40°, and were deposited prior to the fault in that area.

At the mouth of Wadi Barud, igneous gravels are found interbedded with beach deposits, as well as overlying them, and at this place blocks of 500 kilos. in weight occur in them, the main classes of rocks found here being granite, quartz-felsite, and dolerite; while further to the north, opposite the mouth of Wadi Shalala, are a few low hills composed of pebbles of spherulitic felsite, rhyolite, and dolerite, which have evidently come down from the vicinity of Jebel Barud. **Wadi Barud.**

Opposite the place where Wadi Abu Moghat leaves the hills is an escarpment composed of igneous pebbles, overlying some low granite knolls, and stretching the whole of the way to the sea, except where a few knolls of beach and metamorphic limestone break through it. From this point up to the plateau of Abu Sha'ar the whole of the beach plain is covered with igneous detritus. **Wadi Abu Moghat.**

Near the southern edge of the plateau of Abu Sha'ar, between it and the sea, two well-defined beaches were seen. The first occurred about 2 kilometres inland, and ended in a well-marked terrace covered with recent shells, extending north and south as far as the eye could see; the second was a saltpan of moist sand and clay, along the shore-edge of which patches of coral were found. It is evident that here the land is rising rapidly, as the water was extremely shallow a long distance from the land, and sandy islands are forming near the shore. These beaches are evidently synchronous with those found on the shores of the bays of Jemsa and Zeit. **Beach E. of Abu Sha'ar.**

On either side of Wadi Belih mounds of these pebbles occur, and from this point, along the edge of the hills up to and beyond the mouth of Wadi Um Sidri, hillocks of boulders and pebbles rising 45 metres above valley level, run close to the hills, forming a fringe through which the water has cut narrow, steep-sided wadis. For example, on descending Wadi Abdalla near Dokhan, immediately on leaving the lower dyke-hills and entering Wadi Um Sidri, two long ridges of this nature are seen on the opposite side of the valley, one extending southward from the hills and the other eastward, the valley cutting through them as a furrow **Wadi Um Sidri.**

bounded by low cliffs. The gravels are mainly composed of the rocks occurring in the Dokhan and Um Sidri districts, the porphyries themselves being especially conspicuous. The southern branch of Wadi Um Sidri runs for some distance on the junction-line between the igneous rocks and the gravels, but as soon as the gorge in the igneous hills is entered, the gravels entirely disappear. It is probable that these beds border the eastern side of the Red Sea Hills throughout the greater part of their course, the mountain valleys broadening out into wide wadis when they enter the plain, and running between low gravel mounds composed of Red Sea Hill rocks.

Wadi Dib.

Igneous pebbles again cover the surface in the wide plain of Wadi Dib lying between the 'Esh, Abu Had and Zeit hills, and cap low foothills on the western flanks of the latter. Thus, the plains east of the Red Sea Hills are largely formed by gravel ridges extending from the mountains and composed of materials derived from them or from the lower parallel ranges, though in some places, as in the plain where Wadis Dib and Dara leave the hills, they are apparently absent. Judging from the fact that they are now deeply grooved, not only by the valleys coming from the mountains, but also by local water-courses, these gravels are rapidly disappearing, the denuding forces largely exceeding those favouring deposition.

Plain between Jebel 'Esh, Jemsa and Jebel Zeit.

To the east of Jebel 'Esh* the plain lying between that range, Ras Jemsa and Jebel Zeit, is covered by a deposit of igneous pebbles cemented together by a calcareous cement, and containing echinids which have been determined as of Pleistocene age.

Here the following sequence was observed:

Top.	Metres.
1. Greenish marly limestone.	6·1
2. Gritty sandstone and sand composed of quartz and felspar ...	1
3. Igneous gravel and grit cemented by calcareous matter. ...	1
4. Gritty limestone with coral	1

The two upper beds contain a large number of small echinid spines and pectens, as well as species of various *Ostrea* and gastropods.

Gravel beaches of Jebel Zeit.

On the seaward side of Jebel Zeit, igneous pebbles form caps to the older beds, and are cemented together by gypseous material. Along the flank of the range where it is formed of gypsum, these pebbles occur on three well-defined ledges at three different heights. These ledges represent three step-faults, which are well seen in the wadis draining the range. The heights at which these layers occur are 58, 73, and 98 metres respectively. It would thus seem as though the faults were later than the gravels. Along the low plateau on the

*Plate V and VI.

seaward side of this range these pebbles are incorporated in a deposit overlying the coral, and are associated with a fine series of tropical shells, such as *Mitra*, *Columbella*, *Oliva*, *Bulla*, etc. Underneath these comes the coral reef, which has been let down by the fault running along the edge of the range. At the south end of Jebel Zeit, and sweeping round the western flank of the hills and along the sea-shore, is a beach of igneous pebbles from which were collected large *Strombidae*, and nearer the sea *Dentalium*, *Anadara antiquata*, and *Murex ternispina*. Further inland, towards the hills, *Dosinia* and *Hemicardium* seemed to predominate. **Western flank of Jebel Zeit.**

The same character obtains along the edge of the bay near Jebel 'Esh and Ras Jemsa. Here, as in the bay near Jebel Zeit, the water is extremely shallow, and it continues so well out to sea, although the tidal rise and fall is so slight, so that a large tract of land is left bare at low water. Numerous *Cerithia*, large *Murex*, etc., different genera of pelecypoda, and corals were collected here, and the whole conditions point to a rapid elevation of the ground. A large patch of salt-bearing clay bears witness to the comparatively recent rise of the land, as also do the recent shells which are scattered over the surface of this area for a kilometre inland. **Shore of Jemsa Bay.**

On either side of Wadi Dara, and in the plain towards the sea, igneous pebbles are found forming the surface deposits. **Wadi Dara.**

It is a noteworthy fact, that these gravels and conglomerates, on the plain facing the Red Sea and Gulf of Suez, are not conformable to the coral limestone which underlies them, but have evidently been deposited after the rise of the land and when the present lines of drainage had been established. The space of time represented by this unconformity cannot have been very great, as the whole of the deposits, with only one or two exceptions, are now determined as Pleistocene. At the same time the appearance of the shells found in these beds is much more recent than that of those from the older limestones.

It is only recently that it has been possible to form any but a vague idea of the age of these beds. Prior to the microscopical examination of the limestone from near Erment, and the determination of fossils collected by Dr. Blanckenhorn further north, the Nile Valley beds were thought to be Post-Miocene; but there was no evidence to prove this supposition except the fact that they were younger than the fault, which, by analogy, was believed to be late Miocene or Post-Miocene. Since, however, these beds have been shewn to be probably Pliocene, and since, wherever sections are available, there is a marked unconformity between them and the gravels, it follows that the latter belong either to very late **Age of the Gravels.**

Pliocene, or early Pleistocene times. It is almost certain that the gravels on the eastern side of the Red Sea Hills are of the same age as those in the Nile Valley, and as the former overlie Pleistocene beds and in other places contain Pleistocene fossils, they may be safely regarded as belonging to late Pleistocene times. From this is drawn a most important conclusion regarding the age of the Nile as a river. It was stated earlier in this memoir (p. 121) that these gravels were found on the west bank of the Nile opposite Qena; that they contained rocks which could only come from the Red Sea; and that they were apparently continuous with those on the east bank. It therefore follows that these gravels were deposited prior to the existence of the Nile, and consequently that this river did not begin to flow in its present bed near Qena until late Pleistocene times.

When the present channel of the Nile was first established, it had, of course, to cut its bed through these gravels, and in doing so must have carried a good many pebbles down-stream into its delta. It has been shewn by Leith Adams and others that at the commencement of its flow the Nile had a much stronger current than at present, thus it is perfectly possible for pebbles to have been carried as far as from Qena to the Delta. Here then is an explanation of the presence of pebbles of igneous rocks reported by Prof. Judd in the Royal Society's boring at Zaqaziq, which were recognised by Prof. Zittel as resembling rocks from the Red Sea Hills.*

In this report it is stated that igneous pebbles were found at 36·5 metres, 48·7 metres, 51·8 metres, 63·4 metres and at 76·5 metres, while metamorphic rocks were also associated with them. Now the various igneous rocks enumerated in the above report can be matched from the gravels near Qena, and they are also known to occur in the hills drained by wadis flowing into Wadi Qena. The supposition that these gravels may have been derived from wadis to the north of Qena cannot be entertained, as there is no instance of igneous pebbles being found in any of these valleys, nor is there any proof that any of them ever received drainage from the igneous range of the Red Sea Hills. As will be shewn later, the southern end of Wadi Qena was formed in early Pliocene times, thus cutting off any drainage that might possibly have found its way westward to the Nile Valley by any other route, and as it has also been proved that connection between the Red Sea Hills and the Nile Valley by way of the above-mentioned wadi was not established until after the deposition of

* *Second report on a Series of Specimens of Deposits of the Nile Delta*, by Prof. J. W. Judd, 1897.

the Pliocene sandy limestone, it follows that these gravel beds are the only possible source of the pebbles described from the Zaqaziq boring. As a further proof of the source of these pebbles in the deposits of Wadi Qena it may be mentioned that a bed of igneous gravel has been found by Beadnell in the valley deposits 1 kilometre north of Heluan, lying 24 metres above sea-level. This deposit contains the same rocks as are found in the beds around Qena.

The question as to whether these gravels were deposited in an arm of the sea, or in a freshwater lake, is not so easily settled on account of the want of fossils. The evidence that exists is wholly in favour of the latter view. Beadnell has found clays containing fresh-water shells to the south of Qena, while to the north near Farshut and Sohag, he has mapped freshwater tufas containing numerous impressions of leaves, besides many fresh-water gastropoda. It thus seems probable that, as the sea retreated from the Nile Valley, a series of lakes were formed in one of which these igneous pebbles were deposited, and that eventually the barriers between them were broken down and their areas drained, the present river being the result. T.B.

These deposits have also been studied by Prof. E. Fraas on the road between Qena and Bir Ambar.* He notes that the cultivation is bounded by a terrace, rising more or less sharply to a height of 20 to 25 metres, and extending to the foot of Jebel Serrai, at the same time being much cut up by water-courses, usually dry. He further states, following Blanckenhorn, that this is a typical higher terrace of the Nile Valley (Hochterrasse) a blackish clay, 1·1 metres thick, itself covered by a layer of rolled flints. This clay is rapidly replaced by sand, the latter forming the whole terrace 500 metres from the valley boundary. The chief observation made here is the importance of calcareous infiltration, both in the clay and sand, the latter being in places cemented by calcareous sinter, giving rise to a calcareous sandstone, while in other places the carbonate of lime occurs both as nodules and thin veins.

Sufficient has been said above to show that it is impossible in the light of the results from Wadi Qena, to accept the view that these terraces are merely a higher terrace of the Nile itself, they being relics of events which were happening even before the river as we now know it ran in its present bed. At the same time it may be freely admitted that fluviatile action on a large scale must have been taking place throughout this region, probably intimately connected with the climatic changes producing the glacial period in Europe. For Barron's

* Fraas, loc. cit. p. 7.

explanation of the Bir Ambar section (see p. 154). While Prof. Fraas adds no new observations to the work and conclusions of Klunzinger, which are in practical agreement with those stated in this memoir, he calls attention to the interesting occurrence of calcareous tufa in one of the ravines traversed in ascending Jebel Hammamat. This he found to be 5 metres thick, and considers that they must be deposits from a spring, though remarking that its occurrence is very striking in this locality so poor in water, and in connection with a rock so poor in calcium carbonate. From its appearance it might be recent, or at most late diluvial.

It has now been shown by the Survey that this is by no means an isolated case, the subject being specially discussed by Hume in a recent paper.*

Fraas also notes the important terraces at Mathrag and Salam, on the Qena-Qosseir road, and their great development in Wadi Ambagé, the detritus in the former having travelled over 30 kilometres, while the latter are about 50 metres thick, and form four to five separate terraces of detritus. Blanckenhorn has divided the youngest formations of the Nile into three distinct diluvial terraces, which he considers as representing three Pluvial periods, corresponding to the same number of Glacial periods. These he has named the Deckenschotter, Hochterrasse, and Niedersterrasse respectively, and they occur in his type locality, Wadi Sanur, at heights of 58, 33, and 18 metres above the present river-level. The question of the relation of the gravel-beds to the "Great Ice Age" is one that must be taken into account in considering the great change in the climatic conditions of which they are the evidence, and the present Survey memoir contains many facts which will have to be taken into account when the time comes for the subject to be more fully examined. It will suffice here to state that, in agreement with E. Fraas, no evidence has been noted of any glaciation in the Red Sea Hills themselves. Indeed, it has now become imperative to carefully examine the earliest archœological finds with a view to determining whether they afford a clue, even to the slightest changes in climate.
W.F.H.

Sub-Section b.—Older Beach (*Older Pleistocene*).—This deposit is found at various places, forming inliers in the Younger Beach, as well as capping hills higher and more inland than the latter. It was first met with on the north side of Wadi Ambagé, forming the summit

* W. F. Hume, *Geology of Eastern Sinai*, International Geological Congress, 1900.

of a hill of gypsum 158 metres above the sea. At this point it was laid against the sides as well as on the top of the hills, and consisted of a hard siliceous-looking limestone crowded with casts of pelecypoda, various kinds of gastropoda, and casts of several species of corals. On the top of the hill its thickness was not over 3 metres, nor did it seem to extend very far from the edge of the wadi. Near the base of the hill it was covered by the terrace of igneous pebbles previously described as being present in this valley.

The next exposure was found to the north of Qosseir on the road to Suez, and consisted of sandy limestones passing into red sandstones, dipping about 5° in a north-westerly direction. The limestones were full of the casts of *Lithophaga* and other boring pelecypoda.

Supplementary Note on Old Qosseir.—This old site, now only represented by a series of mounds, evidently stood on a coral reef, which is now raised a few feet above sea-level. In this rock large astræan corals and nullipores form the main massive constituents, while the flattened spines of *Heterocentrotus* up to 7·5 centimetres in length are present in the greatest abundance. Casts of univalves (turbiform casts over 2·5 centimetres in length, and *Bulla*), and pelecypoda were also common, cemented in the mass of the rock, which here and there also contained small fragments of metamorphic and igneous rocks (gneiss, etc.). At the base of the coral-reef (which is about 2 metres thick) is a conglomerate, full of pebbles of igneous and metamorphic rocks, among which gneiss, diorite, felsites and the more schistose types were recognized. The town itself has disappeared but fragments of amphorae, blue pottery, and coloured beads, rarely having figures on them, together with much selenite, appear to be not uncommon, judging from private collections at Qosseir, and emeralds mounted in brass have also been obtained here.

Behind the low plateau near Qosseir, and resting directly against the dark metamorphic range are a series of white hills with flat tops. These hills, which in some places are 150 metres above sea-level, consist at the base of a loose, green, friable rock, (probably a marl), while at other points they have distinct reef structure, large radiating corals being abundant, and shells of various kinds being cemented into the rock. Among these *Conus*, *Cypraea* and *Bulla* have been noted, occurring as internal casts, together with pectens and small gastropoda, which are present as external casts. Even on the highest summits of the range at 183 metres above the sea, the basal yellow-green beds, having very hackly limestone* resting on them, were found to lie

* This hackly limestone is probably largely altered to gypsum.

directly on the metamorphic rocks in an apparently horizontal position. On the southern side of the Abu Zeran valley towards Ambagé, rise hills over 100 metres in height. At their base the beds are much tilted and curved, and a great deal of talus has been formed. The rock involved in this movement is a limestone, with regular layers of flints, (the flinty member of the Eocene series), while lying above it, but with obscure junction, is a soft limestone about 6 metres thick, which has been quarried. This is followed above by very ochreous beds containing astræan corals replaced in limonite, the higher beds of the plateau being almost entirely composed of reef-building corals. The summit of the plateau itself is formed of a hackly limestone;* and a layer containing abundant specimens of a Venus-like bivalve. Above this was a mound which consisted of a limestone with Nullipore-like structure and a loose powdery rock with shells resembling *Venus* and *Pectunculus*. The coral rock extends to the north, and by resemblance two red hills on the southern side of the road have been referred to the same formation.

The more western of the hills is composed of an altered limestone, containing many casts of large gastropoda and pelecypoda. W.F.H.

Wadi Hamrawein.

At the point where Wadi Hamrawein† leaves the igneous hills and debouches on the plain, another patch of this rock was found laid against a hill of Eocene rocks which are faulted down here, the succession being as follows:—

Top.

1. Greenish clays.
2. Conglomerate of pink limestone fragments.
3. Hard siliceous limestone.
4. Limestone grit with casts of echinoderms, etc.
5. Pebble conglomerate (limestone).
6. Limestone composed of small shell fragments, etc.

The top of the hill, which was 180 metres above the sea, was obscured by scree, which rendered the completion of the section impossible.

To the east of this point, numerous pieces of coral were found in a bad state of preservation, their septæ in all cases being dissolved out. Scattered among these corals were a number of rounded pebbles of limestone which, when broken, proved in nearly every instance to be "geodes" containing calcite crystals.

* See foot-note on previous page.

† Plate III.

Further down the wadi, limestones cropped out from under the overlying pebble beds; their sequence is as follows:—

Top.

1. Gritty limestone. } Younger Beach.
2. Coarse sandy grit. } Younger Beach.
3. Conglomerate of igneous pebbles. } Younger Beach.
4. Gritty limestone with casts of Lucina,* etc.
5. Coral limestone.
6. Limestone grit, consisting of pieces of shells, small Cerithium* casts, etc.
7. Greenish marls with clay bands.

This deposit abuts on Nubian Sandstone, and to the south of it comes a patch of gypsum against which it is laid.

Further east, and nearer the sea, the beds become more sandy, and thin layers and lenticles of pebbles are seen in the limestone, recalling the appearance of that in the Nile Valley.

The coral limestone in the above section consists almost entirely of compound corals of different genera and species; it is an undoubted coral-reef.

At the mouth of Wadi Hamrawein,† about 1 kilometre from the coast, there occurs an isolated hill forming one of a chain running parallel with the sea-coast. These hills vary from 73 to 109 metres in height, and extend as far north as Wadi Safaja being composed of a hard, gritty limestone full of casts of various gastropods, pectens and other pelecypoda besides coral, and a heart-shaped echinid (*Brissus?*).

On the seaward flank of Jebel Nugara‡ there occurs an area of these deposits (about 2 kilometres wide), extending across the Wadi Barud, and narrowing to a point in Wadi Abu Shalala, from whence it extends along the foot of the Abu Morat range as a narrow fringe. The strata on the flanks of Nugara consist of sandy limestones, calcareous sandstones, and marls, which are undoubtedly the remains of a plateau which has been faulted down and then covered by the more recent gravels. In Wadi Barud, about 1 kilometre from where it leaves the hills, there is a small ridge of these limestones 238 metres above the sea. Here there was a distinct roll in the beds, the dip towards the west being 3°, while that to the east was 2°. **Wadi Barud.**

The following is a section of this hill, beginning from above:—

Top.

1. Hard crystalline limestone, silicified in places and passing into chert, containing nodules of chalcedony.
2. Thin beds of sandstone, alternating with conglomerate in which blocks of granite nearly 500 kilos. in weight are common.
3. Gritty calcareous sandstones with layers of igneous pebbles in them.
4. Greenish clays and marls.

* Field-determination only. † Plate III. ‡ Plate IV.

Coral occurs at the top, and also in a reef near the base. There must have been a gradual subsidence of the land to allow a coral-reef to be formed over a coarse conglomerate.

Three kilometres north of Wadi Abu Morat is a small exposure of Pleistocene limestone, about a kilometre wide, composed of the following members, beginning from above:—

Top.

1. Hard crystalline limestone, which has undergone alteration by water and recrystallization, it contains a fair quantity of calcite crystals. This forms a brown hillock in the plain, with the beds dipping 5° E. Organic remains, if ever present, have been obliterated by secondary changes.
2. Hard crystalline limestone, much stained with iron oxide.
3. Soft white limestone, of siliceous aspect.
4. Greenish marly clay.

Jebel Zeit. In the valleys of Jebel Zeit on the west side, beds of Older Pleistocene age were found containing pectens, while underneath were oyster beds which had undergone a change to gypsum. The wadis run through the gypsum as narrow ravines, one of which had been subsequently filled with sandstone, which had been partly cut back giving rise to a precipitous front. Raised beach deposits also rest high up on the gypsum beds.

On the seaward side of Jebel Zeit* behind the ruined houses, several patches of these beds were found, some lying in the plain, and others capping the gypsum hills. In the plain they consist of a hard siliceous limestone grit, oolitic in places, and filled with casts of *Lithodomus* and gastropoda. Underneath is a compact white bed, gypseous in character, and containing similar fossils to those of the overlying rock. These beds are the same as those occupying the crests of the hills.

On the top of the ridge where the cairn stands, near the Qena road, strata of the same character are found, the top of the cairn-hill being composed of the hard siliceous bed. This stands 43 metres above sea level.

In a valley behind this ridge a case of unconformity was observed, the unconformable rock being a sandstone overlying the limestone previously mentioned. This bed is tilted away from the valley to the west, but has also a dip to the south. On the east side of the valley the strata are dipping steeply into it, this being apparently due to a fault which runs out to sea in a south-easterly direction. The whole of this fossiliferous piece seems to be let into the gypsum by a V-shaped fault running south-east and south-west.

Lying against the gypsum which occurs on the eastern side of the range north-west of the ruined houses, there is a hard siliceous rock,

* Plate VII and V.

oolitic in places, and in other parts crowded with casts of pelecypoda and gastropoda, corals being also present at an altitude of 110 metres above the sea. The fossils in this bed are similar to those found in the limestones in the plain, and there seems little doubt that the latter have been let down by a fault running along the edge of the range. A little further to the north a hard siliceous sandstone takes the place of the fossiliferous strata, but it also eventually disappears. This rock also occurs in a valley which has cut its way right through the range into the sea. Here it is let into the gypsum by a trough fault. T.B.

Sub-Section c.—Coral Reefs and Raised Beaches.—Hitherto in this memoir the coral reefs have been considered rather as components of a raised beach series; they may now be dealt with separately, and an examination of these shows that they fall into several well-marked divisions:

1. The coral reefs at present forming in the Red Sea.
2. The raised beaches and lower coral reefs which flank the coast and vary in height from near sea-level to about 25 metres above the sea, as at Abu Shigeli.
3. A higher coral reef series standing back on an average from 4 to 7 kilometres from the sea, and at variable levels, the mean height being 115 to 170 metres.
4. A disturbed coral reef, dipping sometimes as much as 20° eastward, probably intimately related to,
5. An old coral reef in which the affinities are as much Mediterranean as Erythraean, which is at present assigned to the Miocene (see further).

Coral Reefs forming in Red Sea.

1. *The Coral-Reefs at present forming in the Red Sea.*—Fortunately the general characteristics of these beds have been described in a very interesting manner by Dr. Klunzinger, who in the 6th chapter of his "Oberægypten" has given an excellent wordpicture of the reef as it is developed at Qosseir. The following remarks are based upon his statements, supported by our own examination of the shores of the Gulf of Suez, Red Sea, and Gulf of Aqaba. The reef extends as an almost flat fringe for many miles along the coast, only broken at points where the valleys enter the Red Sea. In places it may become uncovered at low tide, and it is possible to advance to the precipitous edge fronting the sea, but in general this coral plateau is hidden under water, and at Gharib has a strip of water lying between it and the shore. One of the most noticeable of its features is the fact that the reef does not form a continuous plateau, but is full of hollows and cavities, which are aquaria teeming with the most varied life, and often brilliant with colour. Klunzinger has also noted the great blocks of rock which rise from the surface, and which recalled to him in appearance the "erratic

boulders" of North Europe, but these are but part of the reef itself, being formed of the same limestone.

Outer Zone.—In the outermost pools of the reef (in addition to the numerous crabs, worms, etc.), molluscs, which form so rich a part of the fauna of the raised beaches, make their appearance, but are chiefly confined to the two *Neritæ (N. polita* and *N. albicella)*, readily recognized the one by its polished surface, and the other by its weathered appearance. Close to the shore too, hundreds of black *Mytilus variabilis* have attached themselves to the pebbles or reef-limestone by their byssus, while small *Litorinæ* and *Cerithium* are hidden under the stones. *Patella* clings to the rocks, and especially noticeable are the curious Chitons, which abound near the shore. The small pools, are often full of a delicate Ulva-like alga *(Phycoseris)*, while some of the bays, especially near Jemsa, are filled by large green bushes, or trees—the shora *(Avicennia officinalis)*.

Inner shore zone or zone of Green Algæ.—As may be inferred from the name, the next zone is characterized by its green algæ, among which the delicate grass-green *Neritina Rangiana* (for the modern forms the specific names given by Klunzinger are adopted in this description, the Survey collection not having yet been fully examined), two species of *Bulla*, and especially the striking *Canarium gibberulum*, with its bright red mouth, either creep or jump about, associated with the latter being the fine *Pteroceras bryonia*. These two are amongst the commonest finds on the shore, where they have been cast up during storms, or are distinctive members of the youngest raised beaches. Here, too, will be found the large triangular *Pinna*, which frequently attains a length of over 30 centimetres, while empty shells of *Tellina* and *Lucina*, accompanied by *Cytherea*, *Arca*, and *Cardita*, represent the bivalves. Gasteropoda are abundant, especially *Natica*, *Terebra*, and *Nassa*. But perhaps the most striking of all the animals on the flat reef are the Ophiurids, every cavity containing one of these, their snake-like arms being gently waved to and fro with the rippling of the water.

Sea-urchins, too, are found in the holes in the rock, the most common being the *Echinometra lucunter*, covered with small sharp spines, to come in sharp contact with which involves wounds of a most unpleasant description.

Stylophora or *Coralline Zone.*—This zone is at once recognized by the soft algal coating covering the coral reef, by the abundance of the delicate corallines, and by the presence of the branching coral *Stylophora*. The Ophiuridæ are here everywhere in the clefts of the rocks, while a

large-sized *Chama*, and especially the *Monodonta Pharaonis* with its beautiful colouring and pearly interior, have in part replaced the forms above-mentioned. This practically is the region where the Echinodermata have their maximum development, associated with them being a large *Tridacna*, and the beautiful shells of the *Cypræa pantherina*; but for the main features of the rich fauna connected with this zone reference must be made to the work above-mentioned.

Transition-zone to Coral Reef.—A portion of the reef has now been reached which is always covered by the sea, the whole reef being broken up by innumerable lagoons, the sides of whose walls are crowded with corals of every shape and form, clearly visible beneath the transparent water. Among these the Astræan forms, such as *Orbicella*, *Solenastræa*, and *Leptastræa*, large masses of *Porites*, and the brain-corals (*Cœloria*), together with the deep red organ-pipe coral, or *Tubipora*, are the most conspicuous.

Coral-zone.—Finally, the coral-zone itself is reached, and the fact is still more strongly impressed upon the observer that a coral-reef, far from being a compact mass of limestone, is really a system of labyrinthic caverns and deep basins lined with corals, every interspace being occupied by members of the brilliantly-coloured or diversified fauna which abound in the warm waters of the tropical seas. Prominent among the corals in this region is the many-branching sharp-pointed *Madrepora*, forming large bushes, often of delicate yellow tints. *Porites* spreads out in large rounded masses, while the brain-corals with their delicate greenish tints and meandroid windings are striking objects. Here, too, is the home of the Astræan corals, especially the huge *Acanthastræas* and *Prionastræas*, accompanied by the more delicate *Goniastræa*.

2. *Raised Beaches and lower Coral-Reefs*—Returning to the shore itself, it will be found in many places to be covered with shells of every form and description, lying either in long strips or spread over considerable areas of flat marshy ground, from which the sea appears to have but recently retired. Here it is the members of the shallower zones that are most commonly met with, sometimes lying in confused masses, while at other points certain shells occupy special areas.

Thus, as Zeit Bay is approached from the Mellaha hills, on the gently shelving shore, still marshy, and impregnated with salt, are strewn shells of a medium-sized *Strombus*, nearer the shore replaced by *Anadara radiata*, *Dentalium*, and the sharp-spined *Murex ternispina*, which at times attains a length of 10·5 centimetres. Further inland towards the hills, *Dosinia* and *Hemicardium* appear to predominate while some of the dried-up inlets of the bay are crowded

with thousands of a small *Pirenella*. Storm-beaches, too, are very noticeable, *Echinometra lucunter* being scattered along the shore with its spines still intact, associated with it in places being a *Cidarid* bearing large reddish-coloured spines, sometimes 8 to 10 centimetres long (*Phyllacanthus imperialis*).

But, if the shore-fauna itself is rich in shells, it is not to be compared with the varied fauna occurring in the low ridges and cliffs of the raised beaches, which rise 6 to 25 metres above sea-level, and are in places crowded with well-preserved specimens of delicately-marked gasteropoda and pelecypoda, the number of species collected by the Survey in these rocks probably rising into the hundreds (see list of shells pp. 142 and seq.). Corals themselves are comparatively rare in the lowest beds, but the following sea-urchins have been recognized by Dr. Gregory: *Echinometra lucunter*, flattened spines of *Heterocentrotus mammilatus*, the small *Fibularia valva* (its anal aperture being a small opening close to the central mouth), and *Toxopneustes pileolus*. At Qosseir Qadima, at Jebel Zeit and many other points these beaches are however true coral-reefs, astraean corals and nullipores being associated in the neighbourhood of the petroleum wells at Zeit with a large series of tropical shells: *Mitra*, *Columbella*, and small *Fungia*. Above these at the latter locality follows a second ridge containing casts of *Lithophaga* and other pelecypoda, covered by an oolitic pecten-bed, also containing gasteropoda and *Lithophaga*. The summit is formed by a limestone containing pelecypod casts. At the lighthouse of Ras Gharib (outside the area under description) the fauna of the terraces is still more rich in species, but further description must be reserved until these have been closely examined. The corals recognized in these beaches are all of recent character, including *Porites solida*, *Orbicella forskali*, *Stylophora* sp. (25 metres at Abu Shigeli), *Goniastræa pectinata*, and *Goniastræa rectiformis*, from the 15-metres beach at Jemsa (Gregory see list, page 141).

Sufficient evidence is, however, now forthcoming to suggest what are the main faunal differences both between these low raised coral reefs and the modern ones, and also the former and the higher beds next to be considered. A raised beach north of Qosseir gives the typical fauna for these "Lower Coral Reefs," the principal forms being the following Echinodermata, *Laganum depressum*, *Clypeaster scutiforme*, and *Heterocentrotus mammilatus* (represented by its flattened spines), while the characteristic corals are chiefly *Goniastræa* (*G. halicore*, *G. rectiformis*, and *G. pectinata*), *Porites solida*, *Cœloria arabica*, *Orbicella laxa-mammillosa*, *Cyphastræa chalcidicum*, and *Siderastræa*,

these being mainly Pleistocene. These beaches are in the further remarks described as the Laganum Bed.

In some contrast to this is the fauna of

3. *The Higher Coral Reefs.*—These stand well back from the sea at elevations of 115 to 170 metres, and instead of containing *Laganum*, enclose *Brissus carinatus*, closely allied to the *Brissus Ægyptiacus* from the Upper Miocene, and *Clypeaster humilis*, presenting also a suggestive resemblance to *Clypeaster priemi* from the Upper Miocene. The corals, show certain differences; for in the beach of Wadi Hamrawein are missed the *Goniastrœas* and the *Porites*, the *Orbicella laxa-mammillosa* and *Cyphastrœa chalcidicum*, forms of *Leptastrœa* and *Favia* now being predominant, the majority still of recent species, but some having a decidedly Pre-Pleistocene character. The disturbed coral-reefs will be considered under the Miocene beds (p. 161).

Enough has been said to show that there is here an inversion of the stratigraphical arrangement, similar to that observed in the case of river-terraces, the higher beds being the older, this condition of the coral-reefs being described, in his usual trenchant manner, by Prof. Suess in "Die Antlitz der Erde." The only explanation of the conditions now observed involves the conclusion that the coral-reefs have been formed during a period of secular elevation, as had long ago been recognized by Klunzinger and others. It has also been seen that there is apparently a long break between the formation of two of the reefs, the explanation here suggested being as follows:—The first great earth-movement in the Red Sea region appears to have been before the Miocene and subsequent to the Eocene, as near the hills themselves faulting has affected the latter, beds at present recognized as Lower or Middle Miocene being deposited in spaces produced by the dislocation. Later, probably during late Pliocene times, as the result of further movements, coral-reefs commenced to grow on the sides of the igneous hills, but as soon as valleys (owing to continued elevation and denudation) had been formed in the latter, down which torrents brought the detrital materials, the conditions became unfavourable for the formation of true reefs, and only gravels of igneous materials were produced. This view assumes the existence of more marked pluvial conditions than at present, as maintained by Hull, Lyons, etc., and it was only when the present rainless desert-characters were determined that the reefs could again be formed without interruption from disturbing influences. This appears to be the best theoretical explanation of the duplicate age of the reefs at present available, while secular elevation easily accounts for the different levels at which the beds are now found.

At the same time, in spite of the rich fauna already obtained, a still closer palæontological examination might help to clear up some of the outstanding difficulties regarding the age of the older reefs (See Miocene).

NOTE.—Klunzinger's theoretical views on this question occur in the *Zeitschrift fur allgemeine Erdkunde*, XIX, 1865. The most important conclusions are as follows (these being quoted and adopted by Fraas): "The reef-limestones are rocks of the latest formation, with fossil contents agreeing more or less clearly with species occurring in the present sea, according as they are nearer or farther from the coast. These hill-masses, of this newest formation, often rise up to 800 feet above sea-level, but as far as the organisms are concerned, could scarcely have differed from the present sea; they have therefore undergone some process of elevation, a movement which appears to be still in progress."

He adds that even the older inhabitants maintain that what is now dry coral-floor was once sea. It is, as Fraas also remarks, of importance to notice that while Klunzinger perceived that the fossils in the youngest limestone were almost identical with those at present existing in the neighbouring sea, he found certain forms, rare in the latter, very abundant in the raised reef, e.g., *Pecten*, *Spatangus*, the latter probably our *Clypeaster*. In this memoir, these distinctions are carried further, but in no way diminish the significance of such a discovery as that of *Tridacna* in the uppermost beds of the coast-hills several hundred feet above sea-level, such as was discovered by Klunzinger above Qosseir Qadima.

Indeed, all the evidence at present to hand points to the conclusion that even some of the highest coral-reefs are Pleistocene, this showing that important earth-movements have been in progress during very recent periods, and are probably still continuing. At the same time, there is evidence that the land-elevation has not been perfectly continuous, Barron pointing out that coral limestones have been laid down on the surface of recent pebble conglomerates, while Walther and the writer have adduced evidence pointing to the existence of similar local depression-tendencies in Eastern Sinai even at the present time.

W.F.H.

List of Corals and Echinoderms from Raised Beaches bordering the Red Sea from Gharib to Qosseir.

I.—Low Beaches, Gharib, etc.

Echinoderms:—

1. *Echinometra lucunter* (abundant).
2. *Fibularia valva.*
3. *Heterocentrotus mammilatus.*
4. *Phyllacanthus imperialis.*
5. *Toxopneustes pileolus.*

Nos. 1, 3, and 4 are ubiquitous.

VI.—Plain between Ras Jemsa and Jebel Zeit.

Corals:—

1. *Stylophora pistillata.*

VII.—15-Metre Beach, Ras Jemsa.

1. *Goniastræa retiformis.*
2. *Goniastræa pectinata*, Ehrenberg.

VIII.—Beach east of Jebel 'Esh.

Corals:—

1. *Stylophora pistillata*, var. *elongata* L. K.
2. *Siderastræa Savignyi*, Edw. and H.
3. *Montipora*, sp.
4. *Fungia valida*, Verrile.
5. *Orbicella*, sp.
6. *Orbicella Forskali*, Edw. and H.
7. *Cyphastræa serailia.*

Echinoderms:—

8. *Laganum depressum.*

VIII. *a.*— *West of Jebel Mellaha.*

Corals:—

1. *Orbicella laxa-mammillosa.*

VIII. *b.*—*24-Metre Beach, Abu Shigeli.*

Corals:—

1. *Porites solida.*
2. *Orbicella Forskali*, Edw. and H.
3. Cast of *Stylophora*, sp.

VIII. *c.*— *Wadi Hamrawein*

(see p. 132–3.)

Corals:—

1. *Favia*, sp.
2. *Cyphastræa chalcidicum* (Forsk).
3. *Cyphastræa*, sp.
4. *Orbicella laxa.*
5. *Orbicella laxa-mammillosa.*
6. *Cœloria arabica*, var. *leptochila* Ehrenb.

Echinids—

7. *Clypeaster humilis.*

VIII. *e.*—Young Beach near Qosseir.

Corals:—

1. *Goniastræa halicore*, Ehrenb.
2. *Goniastræa* aff. *retiformis.*
3. *Cœloria arabica.*
4. *Cyphastræa chalcidicum* (Forsk).
5. *Cyphastræa*, sp.
6. *Orbicella laxa-mammillosa.*
7. *Siderastræa*, sp.
8. *Porites ? alveolata.*

Echinids:—

9. *Brissus carinatus ?* (*ægyptiacus* Gth).
10. *Clypeaster*, sp.
11. *Laganum depressum.*
12. *Heterocentrotus ? mammillatus.*

XIII.—High Raised Beaches.

XIII. *g.*— *Wadi Barud, 238 m.*

1. *Cyphastræa*, sp.
2. *Cyphastræa*, sp. nov.

XIII. *e.*—*168-Metre Beach, Wadi Abu Shigeli.*

Echinids:—

1. *Laganum depressum.*
2. *Clypeaster scutiforme.*
3. *Brissus carinatus* or *ægyptiacus.*

Mollusca of Raised Beaches.

I.—Low Beaches, Gharib.

1. *Haliotis cruenta*, Reeve.
2. *Capiluna Ruppelli*, G. B. Sowerby.
3. *Capiluna Ruppelli*, var. *Barroni*, var. nov.
4. *Emarginula incisura*, A. Adams.
5. *Scutum unguis*, Linn.
6. *Trochus (Cardinalia) virgatus*, Gmelin.
7. *Clanculus Pharaonius*, Linn.
8. *Turbo radiatus*, Gmelin.
9. *Hipponyx barbatus*, G.B. Sowerby.
10. *Cypræa fimbriata*, Gmelin.
11. *Cypræa isabella*, Linn.
12. *Cypræa turdus*, Lam.
13. *Natica (Mammilla) melanostoma*, Gmelin.
14. *Cerithium columna*, G. B. Sowerby.
15. *Cerithium erythræonense*, Lam.
16. *Vertagus recurvus*, G. B. Sowerby.
17. *Vermetus*, sp. indet.
18. *Strombus fasciatus*, Born.
19. *Strombus fusiformis*, G.B. Sowerby.
20. *Canarium dentatum*, Linn. var. *erythrynum*, Chemnitz.
21. *Cassis (Casmaria) nodulosa*, Gmelin, var. c. *torquata*.
22. *Fusus polygonoides*, Lam.
23. *Mitra Bovei*, Kiener.
24. *Mitra (Chrysame) Ruppelli*, Reeve.
25. *Pisania ignea*, Gmelin.
26. *Collumbella fasciata*, G.B. Sowerby.
27. *Nassa (Alectryon) glans*, Linn.
28. *Sistrum elatum*, Blainville.
29. *Ancilla cinnamomea*, Lam.
30. *Terebra duplicata*, Linn.
31. *Conus nussatella*, Linn.
32. *Conus generalis*, Linn.*
33. *Bulla ampulla*, Linn.
34. *Dentalium ortogonum*, Lam.
35. *Arca imbricata*, Bruguière.
36. *Arca squamosa*, Lam.
37. *Barbatia lima*, Reeve.
38. *Septifer bilocularis*, Linn.
39. *Volsella auriculata*, Krauss.
40. *Alectryonia cucullata ?* Born.
41. *Plicatula ramosa*, Lam.
42. *Cardita calyculata*, Linn.
43. *Cardita (Beguina) gubernaculum*, Reeve.
44. *Libitina oblonga*, Linn.
45. *Codakia fibula*, Reeve.
46. *Venus reticulata*, Linn.
47. *Chione costellifera*, Adams and Reeve.
48. *Sunetta effossus*, Hanley.
49. *Hemicardium (Opisocardium) auriculum*, Forskal.
50. *Chama cornucopiæ*, Reeve.
51. *Chama Jukesi*, Reeve.
52. *Asaphis deflorata*, Linn.
53. *Corbula cuneata*, Hinds.
54. *Corbula Taheitensis*, Lam.

II.—Beach against Old Island south of Gharib Lighthouse.

1. *Capiluna Ruppelli*, G. B. Sowerby.
2. *Nerita albecilla*, Linn.
3. *Cerithium Ruppelli*, Philippi.
4. *Pirenella mammillata*, Risso.
5. *Fusus polygonoides*, Lam.
6. *Murex ternispina*, Lam.
7. *Bulla ampulla*, Linn.
8. *Plicatula ramosa*, Lam.
9. *Donax trifasciatus*, Reeve.
10. *Circe (Lioconcha) lentiginosa*, Chemnitz.
11. *Circe (Crista) pectinata*, Linn.

III.—Beach east of Gharib.

1. *Turbo radiatus*, Gmelin.
2. *Nerita albecilla*, Linn.
3. *Cypræa Arabica*, Linn.
4. *Cypræa caurica*, Linn.
5. *Cypræa turdus*, Lam.
6. *Modulus tectum*, Gmelin.
7. *Strombus fasciatus*, Born.
8. *Canarium dentatum*, Linn. var. *erythrynum*, Chemnitz.
9. *Nassa pulla*, Linn.
10. *Sistrum cancellatum*, Quoy and Gaimard.
11. *Sistrum elatum*, Blainville.
12. *Magilus antiquus*, De Montfort.
13. *Terebra duplicata*, Linn.
14. *Conus miliaris*, Hwass.
15. *Conus nussatella*, Linn.
16. *Glycymeris pectunculus*, Linn.
17. *Septifer excisus*, Wiegmann.
18. *Loripes globosa*, Forskal.
19. *Codakia exasperata*, Reeve.
20. *Circe (Crista) pectinata*, Linn.
21. *Chama nivalis*, Reeve.

IV.—Recent Beach south of Gharib Lighthouse.

1. *Natica (Mammilla) melanostoma*, Gmelin.
2. *Cerithium cæruleum*, G. B. Sow.
3. *Pirenella mammillata*, Risso.
4. *Strombus fasciatus*, Born.
5. *Anadara antiquata*, Linn.

6. *Glycymeris pectunculus*, Linn.
7. *Plicatula ramosa*, Lam.
8. *Eutellina (Peronea=Psammotella) rosea*, Gmelin.
9. *Mactra olorina*, Philippi.*
10. *Callista florida*, Lam.
11. *Circe lentiginosa*, Chemnitz.
12. *Circe pectinata*, Linn.
13. *Tapes virgineus*, Linn.*
14. *Dosinia radiata*, Reeve.
15. *Cardium leucostoma*, Born.
16. *Tridacna gigas*, Linn.
17. *Chama cornucopiæ*, Reeve.
18. *Chama nivalis*, Reeve.
19. *Lutraria intermedia*, Reeve.

V.—Jebel Zeit, Recent Beach.

1. *Trochus (Infundibulops) erythræus*, Brocchi.
2. *Trochus (Lamprostoma) maculatus*, Linn.
3. *Clanculus Pharaonius*, Linn.
4. *Natica melanostoma*, Gmelin.
5. *Cerithium cæruleum*, G. B. Sow.
6. *Vertagus fasciatus*, Bruguière.
7. *Vertagus Kochi*, Philippi.
8. *Strombus fasciatus*, Born.
9. *Strombus fusiformis*, G. B. Sow.
10. *Canarium gibberulum*, Linn.
11. *Terebra Babylonia*, Lam.
12. *Terebra cancellata*, var. *columellaris*, Hinds.
13. *Terebra duplicata*, Linn.
14. *Bulla ampulla*, Linn.

VI.—Plain near Zeit Bay.

1. *Dolium variegatum*, Lam.*
2. *Melongena (Volema) paradisiaca*, Reeve.
3. *Mitra (Chrysame) rubigenea*, A. Adams.
4. *Sistrum elatum*, Blainville.
5. *Oliva (Carmione) inflata*, Lam.
6. *Terebra consobrina*, Deshayes.
7. *Arca rotundicostata*, Reeve.*
8. *Anadara radiata*, Reeve.
9. *Spondylus aculeatus*, Chemnitz.
10. *Venus reticulata*, Linn.
11. *Circe pectinata*, Linn.
12. *Dosinia radiata*, Reeve.
13. *Hemicardium auriculum*, Forskal.
14. *Tridacna gigas*, Linn.
15. *Apollon tuberculatum*, Broderip.

VII.—15-Metre Beach, Jemsa.

1. *Halcioniscus variabilis*, Krauss.
2. *Cypræa erosa*, Linn.
3. *Cypræa turdus*, Lam.
4. *Natica melanostoma*, Gmelin.
5. *Cerithium Ruppelli*, Philippi.
6. *Vertagus fasciatus*, Bruguière.
7. *Turritella trisulcata*, Lam.
8. *Strombus fasciatus*, Born.
9. *Strombus fusiformis*, G. B. Sow.
10. *Canarium dentatum*, var. *erythrynum*, Chemnitz.
11. *Pterocera millepeda*, Linn.
12. *Lampusia pilearis*, Lam.*
13. *Melongena paradisiaca*, Reeve.
14. *Sistrum elatum*, Blainville.
14a. *Pleurotoma Garnonsi*, Reeve.*
15. *Terebra consobrina*, Deshayes.
16. *Terebra crenifera*, Deshayes.*
17. *Terebra duplicata*, Linn.
18. *Conus omaria*, Hawass.
19. *Arca imbricata*, Bruguière.
20. *Anadara radiata*, Reeve.
21. *Glycymeris pectunculus*, Linn.
22. *Spondylus aculeatus*, Chemnitz.
23. *Spondylus*. sp. *indet.*
24. *Cardita gubernaculum*, Reeve.
25. *Venericardia Cumingi*, Deshayes.*
26. *Eutellina rosea*, Gmelin.
27. *Dosinia laminata*, Reeve.
28. *Chama nivalis*, Reeve.
29. *Lutraria intermedia*, Reeve.

VIII.—Beach east of Jebel 'Esh.

1. *Priotrochus obscurus*, Wood.*
2. *Cypræa annulus*, Linn.
3. *Vertagus fasciatus*, Bruguière.
4. *Vertagus Kochi*, Philippi.
5. *Vertagus recurvus*, G. B. Sow.
6. *Turritella trisulcata*, Lam.
7. *Strombus fasciatus*, Born.
8. *Cassis (Semicassis) lævigata*, Defrance.
9. *Oliva (Ispidula) ispidula*, Linn.*
10. *Anadara radiata*, Reeve.
11. *Chlamys Reissi*, Bronn.
12. *Chlamys (Gigantopecten) latissima*, Brocchi.
13. *Cardita gubernaculum*, Reeve.
14. *Circe callipygia*, Born.*
15. *Circe pectinata*, Linn.
16. *Dosinia laminata*, Reeve.
17. *Dosinia radiata*, Reeve.
18. *Cardium rubicundum*, Reeve.*
19. *Chama nivalis*, Reeve.

IX.—Beach No. 2, Plain east of Jebel Mellaha.*

1. *Anadara radiata*, Reeve.
2. *Callista* (like) *costata*, Chemnitz.
3. *Lævicardium* (like) *oblongum*, Gmelin.

* Here the Pleistocene beach overlies a Miocene bed with *Alectryonia Virleti*. Newton also noted *Cardium leucostoma*, Born. from here.

X.—Beach of Ras Shokheir.

1. *Anadara radiata*, Reeve.
2. *Lithophaga Avitensis*, Mayer-Eymar.
3. *Corbula Taheitensis*, Lam.
4. *Martesia*, sp.*

XI.—24-Metre Beach, Wadi Queh.

1. *Trochus maculatus*, Linn.
2. *Turbo radiatus*, Gmelin.
3. *Nerita albecilla*, Linn.
4. *Cypræa annulus*, Linn.
5. *Cypræa cylindrica*, Born.
6. *Cypræa erosa*, Linn.
7. *Cypræa isabella*, Linn.
8. *Cypræa vitellus*, Linn.
9. *Cerithium cœruleum*, G. B. Sow.
10. *Cerithium erythræonense*, Lam.
11. *Vertagus asperum*, Linn. (var.).*
12. *Strombus fasciatus*, Born.
13. *Strombus floridus*, Lam.
14. *Canarium gibberulum*, Linn.
15. *Apollon tuberculatum*, Broderip.
16. *Latirus turritus*, Gmelin.*
17. *Vasum cornigerum*, Lam.*
18. *Nassa pulla*, Linn.
19. *Ancilla (Sparella) acuminata*, G. B. Sow.*
20. *Conus flavidus*, Lam.*
21. *Conus monachus*, Linn.
22. *Conus nussatella*, Linn.
23. *Conus omaria*, Hwass.
24. *Conus virgo*, var. *emaciatus*, Reeve.
25. *Bulla ampulla*, Linn.
26. *Arca imbricata*, Bruguière.
27. *Anadara antiquata*, Linn.
28. *Barbatia lima*, Reeve.
29. *Libitina oblonga*, Linn.
30. *Codakia exasperata*, Reeve.
31. *Codakia fibula*, Reeve.
32. *Tellina remies*, Linn.*
33. *Tellina rugosa*, Born.*
34. *Tellina (Tellinella) sulcata*, Wood.*
35. *Arcopagia scobinata*, Linn.*
36. *Venus reticulata*, Linn.
37. *Circe æquivoca*, Chemnitz.*
38. *Circe corrugata*, Chemnitz.*
39. *Circe lentiginosa*.
40. *Chama nivalis*, Reeve.

XI.*a*.—*24-Metre Beach near Mouth of Wadi Queh.*

1. *Strombus tricornis*, Lam.
2. *Conus textile*, Linn.*
3. *Conus tessellatus*, Bruguière.*

XII.—Raised Beach north of Qosseir.

1. *Lithophaga Lessepsianus?* Vaillant.
2. *Lithophaga Lyellanus*, Mayer-Eymar.*
3. *Alectryonia crenulifera*, G. B. Sow.*
4. *Alectryonia plicatula*, Gmelin.*
5. *Alectryonia*, allied to *crista-galli*, Linn.*
6. *Pecten lividus*, Lam.*
7. *Pecten Vasselli*, Fuchs.
8. *Chlamys Reissi*, Bronn.†
9. *Chlamys varia*, Linn.*†
10. *Codakia exasperata*, Reeve.
11. *Mantellum*, allied to *inflatum*. Chemnitz.*

XIII.—High Raised Beaches.

XIII.*a*.—*72-Metre Beach, Wadi Queh.*

1. *Pecten Vasseli*, Fuchs.
2. *Chlamys (Æquipecten) opercularis*, Linn.*†

XIII.*b*.—*90-Metre Beach, Wadi Hamrawein.*

1. *Codakia exasperata*, Reeve.
2. *Venus reticulata*, Linn.
3. *Dosinia radiata*, Reeve.

XIII.*c*.—*114-Metre Beach, Wadi Abu Shigeli.*

1. *Strombus tricornis*, Lam. or *S. Bonelli*, Brongniart.
2. *Cassis lævigata?* Defrance.
3. *Fusus polygonoides*, Lam.
4. *Lithophaga Avitensis*, Mayer-Eymar

XIII.*d*.*156-Metre Beach, west of Qosseir.*

1. *Venus reticulata*, Linn.
2. *Chama nivalis*, Reeve.

XIII.*e*.—*168-Metre Beach, Wadi Abu Shigeli.*

1. *Venus reticulata*, Linn.
2. *Cardium leucostoma*, Born.

* Only recorded from one locality.

† XII. 8.—According to Blanckenhorn, *Pecten porphyreus*. Chemn. next *P. Reissi*.

XII. 9.—The above writer regards this as *Pecten splendidulus*. Sow.

XIII.*c*. 4.—Referred by Blanckenhorn to a young *L. Lyellanus*.

These notes are added to show the extent of the differences which have arisen between palæontologists regarding detail, but as both agree in considering the above beds as Pleistocene, the stratigraphical conclusions are strengthened.

Since writing the above remarks, founded mainly on the character of the corals and sea-urchins, additional evidence is forthcoming, of the different character of the fauna of the two reefs, in a paper entitled "Pleistocene Shells from the Raised Beach Deposits of the Red Sea," * this being an account of the collections made by Barron in the years 1897-1898. From the attached list it will be at once seen that the Lower Reefs and Raised Beaches contain a very varied fauna, "almost all modern species and most of them well-preserved, many of them retaining their original colour-markings and other characteristic features." At the same time it is to be noted that of the 135 species recorded from them only three are known to occur also in the Mediterranean, these being as follows, the author's name being attached in brackets: *Cypræa annulus* (Issel), *Pirenella mammillata* (Tryon), and *Lævicardium* (like) *oblongum* (Gmelin), a remarkable result when it is remembered that many are otherwise of almost universal distribution in the tropical sea. No further evidence is required to prove how separate the two seas were when these beaches were being formed. The following shells appear to be the most abundant: *Turbo radiatus*, *Natica melanostoma*, *Strombus fasciatus*, *Canarium gibberulum*, and *Canarium dentatum*, *Bulla ampulla*, *Circe pectinata*, and the two *Anadaræ*, some of these being equally common in the raised beaches of the Gulf of Aqaba.

It may be mentioned as an interesting point that the latter deposits find their nearest representatives in the raised reefs between Jebel Zeit and Jemsa, such common Aqaba forms as *Oliva inflata*, *Murex ternispina*, *Glycimeris pectunculus*, *Dolium*, and the various species of *Terebra* being common to both. When the Aqaba forms come to be more closely examined, the resemblance may be found to be greater than is even suggested here.

Though the fossil contents are less marked, there is sufficient evidence in the fauna of the Upper and older Reefs to show that these were formed under very different conditions from those which have been just mentioned. Thus, only a very cursory examination shows that certain genera, such as *Pecten*, *Chlamys*, *Alectryonia*, and *Lithophaga*, decidedly predominate, while these are of the rarest occurrence in the newer beaches. On the other hand, but few of the species of common occurrence in the latter are found in the older strata, though there are some remarkable exceptions which must be considered later.

* R. Bullen Newton (*Geol. Mag.* No. 438, N.S., Dec. IV, Vol. VII, Nov. and Dec. 1900, pp. 500-514, 544-560).

The previously-known distribution of the principal members of the Higher Reef fauna is as follows, following Newton:—

1. *Lithophaga Avitensis*.—Miocene of Germany. Pliocene of Italy.
2. „ *Lyellanus*.—Tertiary of Madeira.
*3. *Alectryonia plicatula*.—Miocene to Saharian of Italy, Egypt, etc.
4. *Pecten Vasselli*.—Pleistocene of Bitter Lakes.
5. *Chlamys Reissi*.—Modern limestone of Azores and Madeira.†
*6. *Chlamys varia*.—Tertiary of Italy, etc.†
*7. *Chlamys opercularis*.—Miocene to Pleistocene.†
8. *Cassis lævigata?*—Miocene of Vienna and Pliocene of Italy.† Thus no less than eight out of the twenty forms known from these beds have a pre-Pleistocene aspect, while five seem to be now entirely extinct.

A close examination of the higher beaches north of Qosseir, and 114 metres above sea-level at Wadi Abu Shigeli, brings out a very suggestive fact viz., that all the species but two, viz., *Codakia exasperata* and *Fusus polygonoides*, are either at present known from the Mediterranean, or from marine formations *in Europe*, so that the Erythræan advance had only just begun. It would almost appear as though the Mediterranean must have extended as far as Qosseir, or at any rate that there was sufficient connection for the two faunas to become slightly intermingled, the *Pectens*, etc., being the last survivors of the once predominant northern race.

That the Red Sea fauna was rapidly gaining the upper hand is shown by the fact that in three of the high level beaches only Erythræan shells are present, while they are also not absolutely absent in the others previously mentioned. This association seems completely to exclude Issel's theory that lake-basins occupied the floor of the Red Sea, and at the same time suggests that some very important geographical changes have taken place subsequent to the formation of the longitudinal rifts, the Mediterranean having only gradually yielded to the Red Sea.

Although not directly dealing with the present area, Prof. J. Walther's well-known work "*Die Korallenriffe der Sinaihalbinsel*" must be carefully considered in connection with our results. Walther, when starting on his expedition, had set himself five questions, to which he has given a series of carefully thought-out answers, and as Hume* has already given his views on these points, the present remarks must be considered as Barron's answers to the same question.

* Hume, *Geology of Eastern Sinai*, International Geological Congress, Paris, 1900.

† We have not had the opportunity of weighing the importance of the criticisms made by Blanckenhorn ("Zeitschr. Deutsch. geol. Gesells." Bd. 53, Hft. I. Jan.-March. 1901, p. 78) with regard to the above species. When he publishes his promised work on the Red Sea fauna, it will be possible to determine the significance of the *Pecten* with greater precision.

1. To what thickness may coral-reefs attain? In the previous section of this report the following are the actual thicknesses mentioned: On the top of the hill near Ambagé they were only three metres, at Old Qosseir two, while at Abu Sha'ar, although the limestones and marls of the Miocene series are over 150 metres thick, the two associated coral-reefs are only 3·6 metres and 3·05 metres respectively.

Thus on this point the results of the study of three separate areas, viz., Red Sea and Gulf of Suez (west) coast, Western Sinai and Eastern Sinai, all lead to the same conclusion, viz., *that true coral-reefs do not attain any great thickness.*

2. What is the basis of a coral-reef? It is evident from a study of Walther's conclusions, that the latter had been especially struck by the fact that coral-reefs had only been formed on sedimentary rocks, and ceased abruptly when the igneous ranges reached the shore-line of the Gulf of Suez.

The trend of his thought is summarized in the following sentence (*loc. cit.* p. 498). "The fossil, and probably also the living coral-reefs of the Sinai peninsula, are based on the outcrops of compact rocks,they are wanting on the softer and crumbly coast-rocks of the Sinai peninsula." But from the writers' experience the limitation to sedimentary rocks cannot be maintained unless in the limited sense that a shelly limestone, or conglomerate of the underlying igneous rock, is present between the solid sub-stratum and the actual reef of compound corals.

Thus, to recall a few examples, near Ambagé the coral limestone rests directly on gypsum, at Old Qosseir on a conglomerate of igneous rocks. To the south of Qosseir the coral-reefs are closely connected with the diabase, though usually with the intervention of green marls. To the west, a soft limestone intervenes between the Eocene limestone and the reef, while at Hamrawein the latter is founded on a limestone grit. At Abu Sha'ar the reefs are in one case based on a coarse grit, and in the other on a limestone, while at Jebel 'Esh the whole fossiliferous reef series directly overlies the granite with the intervention of only a thin conglomeratic pebble bed. Sinai has shown further that coral aggregates can be built up directly on sandstone and sands, and that a fringing reef bounds the whole of the Gulf of Aqaba, although hills of hornblende-granite and gneiss come right down to sea-level. The writers' answer to this question runs thus: *The Reef-Bearing series may be based on any rock, whether igneous or sedimentary, but the actual reef of compound corals is usually founded either on a shelly limestone, or on a grit, conglomerate, or marls formed in many cases of the materials of the underlying sub-stratum, though in the case of sands and sandstones it overlies these directly.*

3. To the third question, viz., What rôle does detrital filling material play in the living reef? Prof. Walther's statements are of much interest and value, but at present, till the detailed study of microscopic sections of the reef have been made, nothing will be added here. Similarly, the answer to Question No. 4, "What alterations do the reef-sediments undergo, when they finally rise out of the water?" will also, it is hoped, be more directly studied when the large series of specimens can be arranged. Amongst the most striking features is the change from the dead-whiteness of the modern dead reef to the dusty-grey tints of the older examples of the same rock, which has been shewn by the above-mentioned writer to be due to the passage from limestone to dolomite by the increase in magnesia. The question now demanding solution is, whence has the latter constituent been derived, as the change apparently takes place after the reef has been raised above the sea-level.

5. With regard to the final question, "What alteration in the form and extension of reefs has there been in the course of geological history?" the answer is found in the preceding pages, where the importance of the division into a Newer and Older Coral series is emphasized, and the importance of the faunal differences pressed home. It may, however, be stated here, that one point noted by Walther, viz., that the newer reef is on an average 10 metres above sea-level, also holds good for the equivalent beds bounding the west coast of the Gulf of Suez and Red Sea, and could well serve as a basis for a theory of origin different to the one at present suggested, viz., that the different positions of the old and new reefs are due to shrinking of the sea-level by faulting or other causes, rather than to a secular elevation of the land itself.

Summary of Changes in the Pleistocene Period.—In a recent paper,* the following important points are claimed as belonging to the Pleistocene period:—

1. The breaking down of an Eocene barrier between the main plateau and J. Abu Had, giving rise to Wadi Qena as we now know it, and permitting the passage of material derived from the igneous ranges, probably into a lake. It may be added that fluviatile action is naturally assumed in the above proposition to account for the transport of the rock-fragments from the Red Sea Hills, and the production of the well-marked fan spreading out at the mouth of Wadi Qena.

2. The formation of gravels of igneous material in the lower portion of Wadi Qena and on the opposite bank of the Nile.

* Barron and Hume, *Notes on the Geology of the Eastern Desert of Egypt*, International Geological Congress, Paris, 1900.

3. The breaking down of this barrier to form the present Nile Valley (this being based on Beadnell's results).

4. The formation of the transverse valley of Wadi Gareya, owing to the breaking down of the barrier joining J. Abu Had and J. Serrai.

5. The formation of coral reefs in the Red Sea, and their subsequent elevation to at least 238 metres above sea-level. W.F.H.

Section II.—PLIOCENE.

Gravels, Conglomerates and Limestones.

Immediately on leaving Qena, and ascending the wadi of that name, low plateaux are seen on both sides of the valley, which extend to the Eocene escarpments of the Arras and El Shadin hills on the west, and those of Serrai and El Jir on the east. On the right of the valley going northward a section showed the following succession from above:—

Top.

1. Loose pebbles of Eocene limestone in sandy matrix, the pebbles being both rounded and in rectangular fragments. 3½ metres.
2. Marls, very friable, of light colour. 8 metres.
3. Fissile sandstone, weathering out in large slabs. 6 metres seen.

The beds appear to dip gently parallel to the valley in the direction of the river, and a feature that at once strikes the observer is the fact, that although in the valley itself the pebbles are much more diversified, igneous rocks of several kinds (granites, red porphyry, or quartz-felsites) being associated with the limestone fragments, none of the former were found in the section above-mentioned.

Igneous pebble conglomerate at Bir Arras.

At Bir Arras, a projecting ridge is conspicuous, consisting of a well-marked conglomerate overlying a finely-grained sandstone. The conglomerate in the escarpment was *largely composed of igneous pebbles* (granite, quartz-felsite, porphyry, etc.), many of them well-rounded, and some 15 cm. in diameter; but on mounting the cliff and crossing the plateau which extends towards Jebel Arras, a change is observed, the conglomerate which at first forms the whole cliff, being succeeded by light sands capped by 5 metres of conglomerate. Nearer the hill the igneous pebbles grow fewer, and finally disappear, being entirely replaced by fragments of oyster limestone and cherts, embedded in a sandy and calcareous matrix, the whole being clearly derived from the Eocene strata of the plateau, until at length the higher Eocene of the foot-hills is reached, at this point no distinct junction existing between the two last-named deposits.

Wadi Gareya.

Opposite Bir Arras, two large valleys enter Wadi Qena from the east, both of which have been examined and mapped. From a distance it can be seen that where the northern one, Wadi Gareya, enters Wadi Qena it has cut through a plateau of whitish rock, which on closer examination is found to consist of a mass of limestone resting on yellowish gypseous marls.

Limestone intercalated in conglomerates in Wadi Gareya.

Advancing eastward up Wadi Gareya, the cliffs on both sides become higher, and fine vertical sections are exposed. On the south of the valley a marly limestone is present high in the ridge between two conglomerates or breccias containing very angular fragments of cherty limestones, patches of current-bedded, fine sand also occurring in lenticular fashion in the breccia. The limestone is also lenticular and thins out rapidly, a second layer of a pink colour, being present a few metres higher up, while the pebbles on the summit of the ridge were quite rounded, the total thickness being 70 metres. A little further east, on the opposite side of the valley, the cliffs again display the limestone, but the latter is here more sandy, layers containing more sand than others weathering with greater difficulty, and giving the whole a bedded appearance. Still further to the east, the limestone disappeared, while the stones in the conglomerate were often over 60 millimetres in diameter. Finally, opposite an old Christian monastery, the following succession, beginning from above, was noted:—

Top.

1. Re-made limestone breccia with chert fragments lying in all directions.
2. The same, but with no chert.
3. Green gypseous marl and bedded ferruginous sandstones alternating.

The limestone here differs from those previously described, being identical with the pink limestone of the Eocene series, while the underlying rocks are either part of the Esna shales, or the Cretaceous marls, most probably the latter.

Pebble gravels contain no igneous rocks in Wadi Gareya.

Immediately on issuing into the plain of Wadi Markh, the conglomerates containing chert fragments ceased altogether, but in it isolated patches of gravel with igneous pebbles were noted, whereas in Wadi Gareya (although now it receives all the drainage from the igneous hills) no igneous rocks have been observed in the conglomerate.

Wadi Um Sellimat.

After leaving Bir Arras, and entering Wadi Um Sellimat to the south of Gareya, considerable variations were noted in the dip of the strata in the northern side of the valley, suggesting rolling, but possibly merely due to slipping. The conglomerate only occurs as a very thin coating on the surfaces of the sandstones and limestones previously described.

In the large valley, Wadi Um Haddat, which runs from the foot of Serrai, the succession from above is well shown:—

Top.

1. Conglomerate with pebbles, over 30 millimetres diameter in parts.
2. Red sandy layer with smaller pebbles.
3. Marly beds with vertical jointing.
4. Red sandy beds with smaller pebbles than those above and a distinct pebble-bed locally developed, 2 metres.
5. Layer of massive sandy limestone, 5 metres thick, passing into a similar rock below, which weathers in a spheroidal manner, owing to the limestone flaking off in curved shells. This becomes very sandy in its more flaggy portions.

On the opposite side of the valley a ridge 9 metres high showed no conglomerate at the top, but an alternation of three beds of sandstone with two of limestone.

In a small valley at the foot of Jebel Serrai a similar succession was observed, viz.:—

Top.

1. Conglomerate with few fragments over 30 millimetres diameter.
2. Flaggy sandstone.
3. Hard sandstone, easily flaked, consisting of sand-grains bound together by a calcareous cement, local pebble-beds being present in the centre, some pebbles over 30 millimetres diameter.
4. Conglomerate with pebbles up to 15 millimetres diameter.

In another valley to the south-west of the main Serrai summit, the cliffs on the sides of the valley presented different features, the one on the west (about 10 metres high) being composed of pebble-conglomerate, containing great fragments of white limestone with beds of red sandstone of finer grain; while on the opposite side the conglomerate rests directly on a massive limestone 3 metres thick.

From the base of J. Serrai to Wadi Um Sellimat the plateau was covered with limestone pebbles, and in the latter valley the southern cliff was entirely composed of the conglomerate except at the base, where finer sandy layers were present. Above these the pebbles rise to 25 millimetres diameter, while at the top of the cliff they are over 60 millimetres.

When crossing the range of hills separating the Wadi Hammama from Wadi Um Sellimat, the contrast between the two sides of the range is very striking. On the east, the Eocene limestones and Esna shales were alone present, except near the pass, where the pebble-bed unconformably overlies the true yellow-green Esna shales, the former having a thickness of 1·8 metres, and in places contains huge blocks of the nodular Eocene limestone, the largest measuring 8 cubic metres. This was especially the case in a wadi on the south of the pass and

running parallel to it. The gravels disappear rather abruptly in the centre of the region occupied by the Esna beds.

On the west, after crossing the pass, the plateau is composed of limestone and chert gravels, in which the fragments are of large size and slightly rounded, resting on calcareous sandstone with minute grains of quartz, and containing two beds of limestone, the upper one composed of rounded nodules, hard and highly crystalline, the lower less compact and apparently containing small organic fragments.

A noteworthy fact is the entire absence of igneous pebbles of any kind in these western conglomerates, although these occur in the main drainage-line of Wadi Gareya.

The main points which result from the above more detailed study of the valleys between J. Serrai and J. Abu Had are:—

1. The conglomerates with limestone and chert fragments only occur on the western side of a line drawn north and south from Jebel Abu Had to Serrai, there having been a continuous ridge joining these two plateaux while the beds were being deposited.

2. The existence of this continuous ridge is inferred because the conglomerate is thickest and contains the largest pebbles near the eastern border of the gravels, and still more strikingly from the fact that no igneous rocks appear to have taken part in their composition, while the latter are now freely found in Wadi Gareya itself.

3. The conglomerates are chiefly met with along the edges of the hills, limestones, at first locally developed, becoming more and more important as Wadi Qena is approached, west and south of Abu Had in places forming a continuous plateau.

4. The conglomerates are directly due to the denudation of the Eocene limestones and marls, the soft character of the Esna shales at the base greatly increasing the rapidity with which wearing away would take place.

5. As a drainage-line does not go straight for a rock wall, the transverse gorge of Wadi Gareya is probably due to a great tectonic change, and indeed, viewed as a whole, the country between Abu Had and Serrai appears to have been faulted down.

6. A general movement of depression is also suggested by the fact that the conglomerates with the largest pebbles occur chiefly at the summit, pointing to an increase in the power of the denuding agents.

Wadi Qena. Returning to Wadi Qena itself, it may be recalled that the conglomerates nearest the valleys on the northern side contain igneous fragments, and the same holds true for the southern side somewhat further to the west.

North of Bir Arras, there were good sections in the foot-hills of Jebel Arras, in one of these the upper beds consisting of a conglomerate of chert pebbles, mostly rectangular in outline, and up to 25 millimetres in diameter, though larger fragments are rare. The lower strata consist of sand-rock, looking as though it had been laid down on a slope, dipping steeply below, and becoming horizontal above. On the other side of the valley, which descends from the hills at this point, the conglomerate is a metre thick, overlying knobbly impure limestone, which itself dies out rapidly, being replaced by conglomeratic bands, thus recalling the conditions in Wadi Gareya.

Following up Wadi Qena, the sandy limestones are seen at the base of J. Abu Had, but in the valley itself only low gravel ridges are present, in which igneous pebbles are abundant, red granite and porphyry being especially noticeable. On nearing Abu Had, isolated knolls of wind-eroded white limestone were met with, these finally forming a series of white hillocks which jut far out from the north-west spur of that plateau into the valley. These sandy limestones, too, wind round into Wadi Abu Had, and lie against the Eocene hills, being overlaid by a conglomerate of limestone fragments, which gives rise to a low plateau in the valley. (See Section II.)

As in the previous case, the sandy limestones are not found outside the area occupied by the Eocene strata, but they probably extend far up Wadi Qena, as the Eocene escarpment is flanked by similar low white hills in latitude 28° N. These, however, were only seen from a distance.

From what has been stated above, it is evident that the southern part of Wadi Qena became connected with its northern part bordering the igneous region after the period of the formation of the limestone conglomerates, such a connection being possibly produced by the breaching of the sandy limestones which brought Wadi Arras—the lower part of Wadi Qena—into connection with the big plains on the east. Wadi Qena evidently underwent this change before the break-down of the Abu Had Serrai ridge, as its conglomerates contain igneous fragments, while in those of W. Gareya and W. Um Sellimat these are entirely absent. W.F.H.

Valley Limestone and Conglomerates south of Qena.—These occur all along the plain between the cultivation and Jebel Serrai. They form a low plateau 17 to 20 metres high at the edge of the cultivation, and slope gradually up to the foot of the limestone cliff of Jebel Serrai. This plateau is much cut up by drainages which have steep cañon-like sides, owing to the nature of the rocks which compose it. When these

deposits are followed back from their junction with the Eocene the following changes are noticed:—

1. On the junction line, breccias of flinty and cherty limestone with thin lenticles of limestone interbedded.
2. Conglomerates composed of well-rounded pebbles.
3. Pure white limestones, perhaps slightly siliceous.
4. Marls and clays.
5. On the edge of the cultivation, sandy clays with a good deal of lime in them. These are much worked for manure.

This section seems to represent the sequence from above downwards. As far as could be noticed there was practically no dip; therefore it follows that the beds seen on the edge of the cultivation are the lowest in the series. This would agree with what would be expected in a subsiding area. As the land subsided, clay and sand would be first deposited in the shallow water, and as the water deepened and became clearer, marls first and then limestones would be laid down. The thickness of these beds is unknown as their base has never been seen. They undoubtedly stretch right across the Nile Valley underneath the river alluvium.

In Wadi Qena the sandy limestone of this series is found lying 273 metres above the railway station of Qena. As according to the levels of the Irrigation Department this town is 74 metres above the sea, this limestone now lies 347 metres above datum. But these figures cannot represent the total subsidence, as the base of these deposits has not been seen. If the section given earlier in this description be correct (and there is no reason to doubt this), then at least 200 metres of deposits are known, and as the basal bed of the section is a sandy clay, it is fair to assume that this is not really the lowest bed of the series. This assumption is based on knowledge obtained from borings made for water at different points in the Valley to the north of Qena. At Nag Hamadi a boring has been carried down over 60 metres below the surface without reaching the bottom of the sands, which occur in every boring for water which has yet been made. In the Delta, too, a boring has been carried down 165 metres, for the greater part passing through the sands in question. It therefore seems justifiable to assume that the sandy clay seen at the level of the cultivation near Qena, is not the lowest member of the series, and that in all probability these sands are present at the base. This is, in fact, undoubted, as they have been found underlying the sandy clay which occurs at cultivation-level a little distance to the south of Qena.

These considerations open up a wide field of speculation concerning the movements which have taken place before and after the deposition

of these beds. Before the mapping of this district, the only evidence of a marine fjord in the Nile Valley was the presence of a + 70 metres sea-beach behind Cairo, marked by borings of molluscs, and another at the entrance to the Fayum. Assuming a uniform subsidence, this + 70 metres would carry the sea to near Girga, but this does not account for the presence of the limestones in Wadi Qena and southwards. In view of the thickness of the beds in this wadi, it is necessary to assume unequal subsidence to obtain the results seen.

Returning again to Wadi Qena, it was stated previously that the sandy limestones were found lying 347 metres above sea-level; it is therefore evident that a rise to over that amount must have taken place. The question now arises: To what extent did this subsidence affect the surrounding country? As has been previously stated, the base of these deposits has not been seen, but every evidence goes to show that there is a fair thickness of them. Since these beds, at present, lie 347 metres above sea-level, it is safe to postulate that the subsidence was at least equal to, or over that amount; for it is certain that limestone would not be the last bed to be deposited, unless there were a sudden uplifting movement. Of this there exists no evidence, but, on the contrary, everything points to a slow, gradual depression and rise.

The faulting which has been shown to be the origin of the Nile Valley, is now also known to have produced the Wadi Qena. That these faults belong to the same period of disturbance is undoubted, and it is very probable that before the sea could reach the Wadi Qena by way of the Nile Valley, an interruption of the drainage of that area would take place, and a lake be formed which would at first be fresh, and into which the sands, found below the limestones and marls, were carried and deposited. As the sea advanced up the valley this lake would become absorbed into it, and marine beds would be formed.

The level at which these beds now lie would carry them well up Wadi Qena to the north, and eastward into Wadi Nagateir. In this respect it is interesting to find in an old Roman excavation on the road to Um Disi a section shewing bedded sands similar to those met with in borings in the Nile Valley. How far these sands extend up the so-called Wadi Qena is not at present known. T.B.

In view of recently published papers (see later) it is necessary to re-considerer the whole question of the evidence for a marine extension up the Nile Valley. In 1886, Professor Mayer-Eymar, in a paper entitled "Zur Geologie Ægyptens"* called attention to the borings of *Lithodomus*,

* Viertel Zeitschrift zurich. Naturf. Gesellsch. August, 1886.

etc., and oyster beds occurring at the western foot of the Moqattam, and re-examined the well-known Clypeaster beds, near the Giza Pyramids. In sands close by, he found that more than half the species are such as occur in the Mediterranean at the present day, but are associated with a few mio-pliocene or new forms, and thus arrives at the conclusion that from all the data to hand, the Nile Valley was in very recent times, *i.e.* about 6000 years ago, once more under the sea, at least as far as Assuan. Dawson* has also shewn both the Nile and Jordan valleys as long thin arms of the sea during his Pluvial period. Mayer-Eymar, however, goes a step further than Dawson, as he considers it impossible that the Egyptian Diluvial sea should be only limited to the Nile Valley, and points out that he himself has found distinct marine detritus (Meeres-gerölle) about 150 metres above sea-level (north-west of Minia in one of the big valley openings. This carries him a very wide step further, viz., that the whole Sahara was not only under the sea, but was connected with the Atlantic Ocean otherwise than through the Straits of Gibraltar, the Egyptian fauna he obtained from Wadi el Mellaha having quite a number of species now either only living or commonly distributed on the coast of Senegambia. The Egyptian forms present, are, however, much reduced in size, and this he explains on the assumption that the sea-water was abnormally cold. He finally concludes that during the period of the great Ice Age the higher hills of Egypt were covered with ice, at least during the greater part of the year, and the Nile, entering the sea at Assuan, carried ice during the same period.

These wide theoretical views were unsupported by any direct evidence south of Minia, but in 1896 Barron found a limestone in the Nile Valley near Erment (close to Luxor) containing not only traces of pelecypod shells and echinoderm spines, but fairly numerous, though small, foraminifera, comprising the genera and species *Textularia* (*T. sagittula*, Defr., and *T. agglutinans* d'Orb.), *Globigerina conglobata*, Brady, *Gypsina vesicularis?* Parker and Jones., *Amphistegina Lessonii* d'Orb., *Operculina ammonoides* Gronovius. Beadnell also subsequently found these beds in the Valley of the Tombs of the Kings, near Luxor, etc. These identifications and the discussion of their distribution pointed to the marine origin of the beds containing them, but recently Dr. Blanckenhorn† has attacked the general conclusion arrived at, maintaining after a critical analysis of each species that *the foraminiferal fauna does not mark any particular Tertiary age, and in*

* See *Modern Science in Bible-lands.*

† *Neues zur Geologie und Palaontologie Ægyptens.* II. *Das Palæogen. A Das Eocan, zeitsch, d. Deutsch. geolog. Gesellschaft. Jahrg.* 1900, pp. 407-409.

any case has no specially Pliocene character. The abundance of the Operculinæ would on the contrary suggest their derivation from the neighbouring Lower Eocene rocks.

He further considers this proved by the fact that the foraminifera occur in layers along the lines of stratification and parallel to one another, and finally regards these " Trümmerkalke " as probably similar to those he himself met with opposite Feschn and at Wadi Sanur, which he was inclined to classify as chiefly of upper diluvial age, his so-called "Nieder-terrasse," and also in part to the fluviatile Upper Pliocene, or his freshwater Melanopsis zone.

In addition Chapman has since shown that *Globigerina conglobata*, and *T. agglutinans* do occur in the Eocene rocks of Sinai.

Under these circumstances, the marine age of these limestones, as far as the palæontological evidence is concerned, must be considered *sub judice*, but, on the other hand, sufficient has been said in the previous pages to show that these beds are by no means limited to the Nile Valley; even in the valley itself, *e.g.* at Erment, these limestones are nearly 200 metres above present river-level, and consequently cannot be a mere local deposit connected with that river only. It is not the usual custom for rivers to deposit vast masses of limestone such as those forming the low plateaux along the foot of Abu Had, and for ourselves the only conclusion possible (if we exclude the foraminifera) would be that they are lacustrine, though the absence of any of the fauna of Blanckenhorn's lacustrine Melanopsis-stage is as serious an objection as the lack of the marine types of the *Ostrea cucullata* beds. The Wadi Qena limestone remains one of the conundrums of Egyptian geology.

It is unfortunate that throughout this vast series no further and larger fauna has been obtained, but we are here dealing with a formation directly owing its origin to the rifts (generally regarded as having been formed in or about the Middle Pliocene and long anterior (the igneous gravels being unconformable) to the Nile in its present form. These beds are here included with the Pliocene on the following grounds:—

1. They have no resemblance to the known Miocene beds of Egypt.
2. They are formed in the areas between the rift-fault, and are consequently either Middle Pliocene or later.
3. The Pleistocene igneous gravels are younger and unconformable to them.

Finally, these beds can only be lacustrine or marine, though the conglomerates intercalated with them near the Eocene cliffs may, of

course, be connected with torrent or other action, but also may equally owe their origin to currents.

It is certainly remarkable that while the freshwater horizon of the Nile is characterized by such forms as *Melania*, *Neritina*, and *Paludina*, not a single shell has yet been found in any of the Wadi Qena limestones.

Latest literature.—Dr. Blanckenhorn has published his results * with the avowed object of obtaining priority, in view of the fact that M. Fourtau in Cairo and M. Depéret in Lyons were engaged in writing upon the same subject. With regard to the Pliocene period he adopts the following theoretical conclusions: The Middle Pliocene is the period of two great double fracture-movements, the Nile Valley being a rift formed in part on the line of a synclinal. The invading sea belonged to the third Mediterranean period, and its marine beds were traced by the writer as far south as Wadi Dahaibe to latitude 28° 52′ N. at 30 metres above the sea.

This marine invasion of short duration, was followed during the Upper Pliocene and Lower Diluvial periods by a series of half-brackish lakes, whose level was higher than that of the original sea, and important streams flowing into them formed the oldest terraces (Deckenschotter) and also cones of detrital materials at their mouth. Sandstone was deposited in these lakes, and contains *Melanopsis Ægyptiaca*, as well as species of *Melania*, *Neritina*, and *Vivipara*. He sums up the history of the Nile Valley as follows: In consequence of tectonic changes it was first a fjord of the Mediterranean, then a chain of lakes, and since the Middle Diluvial period a river valley. Where these views differ from those in this memoir is that they take no account of the vast series of limestones occurring in Wadi Qena and spreading from Qena southward, which are regarded here as the direct result of the faulting.

Issel, A.—This writer has attacked these questions from the Red Sea side, and presses the following points: † (1) That the Arabic depression (practically the Red Sea) was originally a lake; (2) The Nile entered this lake during the Pliocene period; (3) The Red Sea was formed quite recently, *i.e.* in post-Pliocene times, by the opening of the straits of Bab-el-Mandeb; (4) For a short time there was communication between the Mediterranean and the Red Sea by the estuary of the Nile; and (5) a series of complicated up and down movements are suggested.

* "Das Neogen in Ægypten and seine Pectinidenfauna," *Centralbatt fur Mineralogie*, etc., 1900, pp. 209-216.

† "L'origine de la formation de la Mer Rouge." *Bull. Soc. Belge Géologie*, avril 1900.

The 1st proposition is not improbable, though proof is wanting, the 3rd may be accepted with the modification that the invasion of the sea had begun in Pliocene times, while the 5th must remain open. In support of this second argument Issel points out that the central zone of the Isthmus of Suez is mainly covered by Nile mud sediment, while at Shaluf-el-Terraba are thick beds of *Ætheria Caillaudi*, and the alluvium contains remains of *Hippopotamus* and fish, the fourth being brought in to explain the mixture of European and Erythraean types noted by Mayer-Eymar in the environs of Cairo.

Beadnell,* has also brought together the results of his detailed examinations in the Nile Valley showing: (1) The importance of the faulting bounding the cliffs from Sohag to Esna, as bearing on the origin of the Nile as a rift-valley; (2) The distribution and nature of the Valley Deposits, which are recognized as divisible into three series—(*a*) Marine beds, a conclusion based on Chapman's identification of the foraminifera above-mentioned; (*b*) Lacustrine, and (*c*) Fluviatile. It is evident from his hesitation as to the marine limestones (*a*) that the theory of the origin of the foraminifera from the Eocene deposits had been considered by him somewhat carefully. His views as to the succession of events is briefly as follows:—The Nile Valley was first due to the Rift-faulting in Lower or Middle Pliocene times, an arm of the sea extending up it at least as far as Esna, then gradual elevation led to the formation of a series of freshwater lakes, in which calcareous tufas, etc., were formed, and finally, in later Pleistocene time, the Nile itself carved its channel through the valley deposits, and the present river commenced its career, depositing the Nile Mud. W.F.H.

Section III.—MIOCENE ROCKS.

In 1887, L. H. Mitchell,† discussed the existence of Upper Miocene beds in the neighbourhood of Ras Jemsa and Jebel Zeit, and claimed a wide extension for these strata between the Red Sea Hills and Gulf of Suez. Thus "in the Great Plain, south-west of Wadi Mellaha, the hills and ridges rising out of the detritus that covers the region, exhibit, *in situ*, the remains of what were once extensive beds of brown, argillaceous and calcareous sandstone impregnated with mineral salts, brown marl, very fossiliferous; greenish-coloured siliceous marls; greenish or drab-coloured argillaceous sands, and marl deposits more or less filled with shells of *Ostrea crassissima*, *Ostrea gigantea*, and *Placuna*."

* International Geological Congress Report, Paris, 1900.

† Report on the Geology and Petroleum of Ras Gemsah and Gebel Zeit, p. 26. Cairo 1887.

Again, on the south-east of the plain, near Jebel 'Esh, he finds soft white limestone, the remains of old indurated coral beds, while in Wadi Dib were remnants of limestone, conglomerates, etc. Abu Sha'ar is regarded as of similar origin, the typical succession being usually sandstone above, yellow marl below, and limestone between.

Abu Sha'ar. The plateau of Abu Sha'ar, is a V-shaped area rising 182 metres above the plain, bounded on the south, east, and north by steep sides, and gradually merging into the plain on the west at a height of 390 metres above the sea. On the seaward side which is bounded by a fault, it consists mainly of a hard, crystalline, siliceous-looking limestone, with occasional marly beds containing quartz grains. In the latter strata, casts of gastropoda and pectens occur; while corals are found from the top of the plateau downwards. The hard crystalline nature of the rock is probably due to changes produced by the movements which culminated in the above-mentioned fault. Along the foot of the cliff occur the wells of Abu Sha'ar, which seem to owe their origin to the line of fracture which bounds the scarp; round them is a patch of gypsum, which is probably the faulted down limestone converted by the agents mentioned in the chapter on gypsum.

The plateau, as was seen further north, rests on a ridge of andesitic rock which is evidently a part of the Jebel 'Esh mass. The limestone forms only a very superficial covering, as is shown at a point about half-way between Wadi Belih and Bir Abu Sha'ar, where it was breached, exposing the igneous rock underneath. The latter rock has evidently been the determining factor in deciding the direction of the fault, as in no case was it found to be far from the edge of the plateau. From the mouth of Wadi Belih, the coral limestone was seen extending away towards Jebel 'Esh, against which it ended; but it was continued along the eastern flank of the range, being plastered against it in patches which in many cases formed higher points than those of the hills. These will be described more fully later on.

Wadi Belih. On entering Wadi Belih, it was seen that the andesitic rock formed the greater part of the cliff, the limestone merely capping it. Further up, the igneous rock rises up above the limestone, the latter bending away northwards behind the former and reappearing again about 2·5 kilometres further to the west, where it again caps the andesite. From this point the igneous rock slopes down quickly and disappears under the limestone. In the bed forming the top of the cliff there occur numerous pectens, but owing to the hardness of the rock it was impossible to get out any complete specimens. After the andesite disappeared under the surface, the sides of the wadi were composed of

perpendicular cliffs of hard, white limestone about 60 metres high, in which fossils were rare. Above this came a rock full of corals (Reef 1 of field-book), but between this and the white limestone came a bed of coarse quartz and felspar grit shewing false-bedding. The following is a section examined in the sides of the wadi, the thicknesses being estimated by eye on account of the inaccessible nature of the cliffs:—

Top.	Metres.
1. Gritty bed with siliceous limestone at the top	15
2. Siliceous limestone with coral and casts of Cytherea, and boring *Lithodomi.* (Reef 2)	3.05
3. Limestone coloured by iron	3.6
4. Greenish marl full of quartz and felspar, and containing three thin beds of marly limestone.	45.0
5, Limestone grit	24.5
6. Gritty marl (Pecten marl)	12.2
7. Coral limestone (Reef 1)...	3.6
8. False-bedded coarse quartz and felspar grit, containing *Ostrea.*	4.5
9. Hard, pure, white limestone	60

From this point up to the foot-hills of the main range isolated knolls of these rocks were passed, which gradually became obscured by gravel.

The beds in the plateau of Abu Sha'ar lie almost horizontal, there being only a small dip of from 2° to 3° to the west.

On its northern side they lie on the tilted strata of the Eocene and Cretaceous beds of Jebel Mellaha which are here cut off by a fault. There has evidently been a barrier of Eocene Limestone, which formed the shore-line of the sea in which these beds were deposited, and supplied the materials to form the gravels which lie on the flanks of the plateau.

On the western flank of Jebel'Esh these beds rest on the top of the Nubian Sandstone, but the latter does not extend south of the fault which crosses the range in an easterly direction, and apparently limits **Jebel'Esh, etc.**
the extension of this limestone to the north. Patches of coral limestone occur on the eastern flank of Jebel 'Esh,* Jebel Um Dirra, at the mouth of Wadi Mellaha, and on Jebel Abu Had. The following may be taken as representing the composition of these reefs:—

Top.

1. Coral limestone containing pelecypod casts.
2. Limestone full of casts of various fossils.
3. Conglomeratic pebble bed.
4. Remade granite.

The chief point of interest about these beds is the part they have taken in the earth-movements, the limestone forming a fringe dipping

* Plate VI and V.

steeply eastward, and being plastered along the whole eastern face of the granite of the above-mentioned ranges. This is all that is left of the Miocene limestone plateau which undoubtedly existed on the seaward side of the range, and was subsequently let down by a fault during the elevation of the hills. Prior to the deposition of this older reef a fracture must have taken place along the line of this later fault, as the Tertiary and Cretaceous rocks which are seen on the western side of this hill-mass, are thrown down beneath the surface.

On the western flank of Jebel Mellaha, isolated patches of probable Miocene Coral reef are also found resting on the Flinty series of the Eocene Limestone (For the relations of these rocks see Section I).

According to Mitchell "between Ras Gharib and Bir el Nakhl, the remains of the Miocene series form massive chains of hills and ridges running in an easterly and westerly direction. They show a development on a large scale of soft, white limestone, gypsum, and yellowish-white, coarse, compact, fossiliferous limestone, subordinated to these being beds of dark brown sandstone, marls, etc.

"Between the Gulfs of Gemsah and Zeit, a series of ridges or hills, rising from the detritus of the plain, exposes to view massive strata of soft, white, tough limestone, the texture of which has the appearance of fish-roe. There is some siliceous matter in its composition. There are also strata of yellowish-brown calcareous sandstone (sand particles cemented with carbonate of lime), and pale yellow limestone beds made up of fossils; also shell-beds full of *Ostrea crassissima* and *O. Virleti.* The strata of these beds dip at an angle of 5° to 10° in a north-westerly direction towards the sea. Westerly and south-westerly from the Gulf of Gemsah, the remnants of extensive areas of these fossils or shells are embedded in strata of calcareous and conglomerate sands."

Finally, basing himself on identifications of oysters made by Prof. Mayer-Eymar, he announces the existence of Upper Miocene in the Great Plain east of the Red Sea Hills and in the Coast Plain of the Gulf of Suez, as well as in the Jafatin, Shadwan, and Jubal Islands.

In the plain between Jebel Mellaha and the Dokhan range, near the road from the latter place to Qena, the following succession was seen in some low mounds:—

	Metres.
Top.	
1. Conglomerate of igneous pebbles in a calcareous matrix	6·1
2. Oyster bed (determined as *Alectryonia Virleti*)	1·2
3. Sandy limestone with various pelecypoda and echinids	3·6
4. Sand and igneous pebbles in a calcareous matrix	0·9
Base.	

The large oyster-beds above-mentioned are undoubtedly of wide distribution, having been obtained in green-coloured low foot-hills west

of the limestone range at Bir Mellaha,* in small ridges at the west end of Zeit Bay, and at the southern end of Jebel Zeit itself, and in the plain of Wadi Dib, closely associated with oolitic limestones, while similar beds, layers of salt, and sandy limestone, etc., overlie the gypseous strata (Eocene or Cretaceous) at Bir Abu Nakhla. These Oysters have been referred by Bullen Newton to *Ostrea Gingensis*, Schlotheim, sp. a Miocene form,† so far confirming the conclusions arrived at by Mayer-Eymar, while still more recently in a Preliminary Notice in the Geological Magazine he has identified the oysters present as of Upper Miocene or Tortonian age. Further evidence pointing in the same direction is derived from Dr. Gregory's identifications of the corals and sea-urchins from these districts. Thus, certain corals from Reef No. 2, Wadi Belih, and the summit of the Abu Sha'ar plateau are regarded by him as probably Pre-Pleistocene, it being further stated "that some forms are probably descended from Mediterranean Miocene species; but these also occur in the Red Sea and Indian Ocean, and only indicate an ancient connection of the Mediterranean and Indian Ocean, probably across Persia and Armenia; such a connection has been advocated from a study of the living deep sea corals of the Indian Ocean by Alcock."

Dr. Gregory divides the collections received into two faunas, the first Pleistocene, or at least Uppermost Cainozoic, while the second (which bears on the present question) is of older age, represented by two imperfect specimens of *Echinolampas* allied to *E. insignis*, Pomel, from Dara hill, west of Dara. A *Leptastraea* and *Favia*, from Abu Sha'ar, near Wadi Belih, also differ markedly from their nearest living allies, and probably belong to the older fauna.

Blanckenhorn‡ has also examined the collections obtained by the Survey at Abu Sha'ar, and announces that beds there contain one of the commonest of the Miocene Pectens, viz., *Pecten Sub-Malvinæ* Blanck., with the addition of *Pecten cf gigas.* Schloth., *Ostrea gingensis*, Schloth var *setensis*, Blanck., and *O. digitalina*. The large *O. gingensis* is not found in Abu Sha'ar itself, while the Pectens are in many cases far larger than the typical *P. Sub-malvinæ*, whose greatest length is given by Blanckenhorn as 48-51 mm. Specimens in the Museum in Cairo attain lengths of 60 centimetres, and have an average of 22 longitudinal costæ. Both the ribs and the interspaces show a complex spinose ornamentation due to the crossing of lamellose and concentric

* *Placuna* was obtained here in addition to the typical Oysters.
† Newton, R. B., *Geol. Mag.* May, 1899, p. 204.
‡ "Zeitsch. Deutsch. Geol. Gesell." Band. 53, Jan. March, 1901, p. 79.

striations agreeing with that found in *P. Malvinæ*. These identifications of the Pectens as Middle Miocene also involve the tilted reef No. 4 previously mentioned, as well as the Reef No. 2 of Wadi Belih, so that the Miocene series of the Eastern Desert falls into two markedly separate series, the Pecten limestones below, and the *Ostrea gingensis* marls above.

Limestone Hills of Dara.—In the plain north and south of Wadi Dara are Miocene deposits containing corals and a good many quartz grains, the former being apparently similar to those of Abu Sha'ar. Further to the north, these beds were found lying on the uptilted ends of the Nubian Sandstone, itself dipping to the south-west at an angle of 12°. In this area the succession was as follows, from above:—

Top.	Metres.
1. Limestone, containing corals	—
2. Bed of *Lithothamnium*	1·9
3. Heterostegina limestones with pectens and echinoderms*	4·5
4. Coral Limestone	1·3
5. Nubian Sandstone	—

Still further to the north, these strata were seen resting unconformably against the edges of the Nubian Sandstone, the former dipping 10° S.W., while the latter is tilted 30° to the N.E. Further to the south-west, the Miocene beds show a dip of 8° to the north-east, thus forming a small syncline, this being due to the faulting which has thrown down the Eocene against the Nubian Sandstone, the movement being continued after the deposition of the younger beds. (For the relation of these beds to the others see Section III.)

General Conclusion.—It therefore appears that shallow-water Miocene beds, connected with the larger Mediterranean Sea, were laid down on the Eocene, etc., unconformably, subsequently taking part in the greater earth-movements forming the Red Sea Hills, the Pecten limestones forming marked plateaux or flanking the igneous hills, while, owing to their comparatively soft nature, the *Ostrea gingensis* marls are only preserved in the synclinal folds, where igneous gravel beds have in many cases overlaid and thus protected them from further denudation.

In the paper already referred to (Das Neogen, etc.) Blanckenhorn,† who enjoyed the exceptional opportunity of being able, not only to examine the Survey collections as they came in, but also to study those made by Schweinfurth and Mitchell, appears to have arrived at the conclusion that all the marine Miocene beds of Egypt, are, as Fuchs

* Schweinfurth's collection here yielded *Heterostegina depressa*, *Echinolampas amplus*, *Ostrea Virleti* and *Pecten triangularis* (loc. cit. above, p. 80).

† See "Zeitsch. d. Deutsch. geolog. Gesellschaft" Bd. 53, Hft. I., Jan.-March, 1901, pp. 52-132, for further description of occurrences noted by Schweinfurth.

had already suggested for those known to him, equivalent to the Grunder Schichten of the Vienna Basin, thus belonging to the base of the Second Mediterranean or Lower Helvetian Middle Miocene. It must be confessed that, if the palæontological data allow of it, it would be a decided advantage to be able to regard all these strata as the result of one great movement of depression, rather than to admit two invasions of the sea, each leaving evidence of its action in different localities. It must be sufficient here to call attention to the difference of age determination, though happily all are agreed in regarding the beds in question as Miocene. T.B. & W.F.H.

Section IV.—EOCENE ROCKS.

The Eocene limestones, etc., are very widely developed on both sides of the Red Sea Hills, and fall naturally into three divisions which will be separately considered. These are:—

A.—The Eocene plateau west of the Red Sea Hills, and the outliers connected with it.

B.—The Faulted Eocene areas south of latitude 27° N.

C.—The Eocene Range parallel to the Red Sea north of latitude 27° N.

A.—The Eocene plateau west of the Red Sea Hills.—From Qena the boundary of the northern limestone plateau extends north-eastward, sending out two bold spurs towards Wadi Qena, viz., Jebel el Shadin and Jebel Arras. On ascending Jebel Arras from Bir Arras, the gravels having been crossed, isolated masses of nodular limestone are seen cropping out in the foot-hills. In front of the main escarpment runs a somewhat lower range, which on examination is seen to be crowned by a hard, crystalline, nodular limestone, and in places by a still higher limestone containing abundant specimens of a small nummulite. Between these hills and the main range a valley runs in a north and south direction, forming the sides of which were horizontal marls containing abundant examples of *Pecten*, and in consequence termed the Pecten Marls. **Jebel Arras.**

An examination of the beds from this point up to the summit showed the following succession, commencing from above:—

Top.

1. Limestone with chert bands.
2. Nummulite limestone.
3. Nodular limestone. (The limestone with bands of flint was obscured here.)
4. Marls with bands of hard limestone.
5. White limestone weathering pink.
6. Pink marls.
7. Unctuous clay.
8. White marls.

The thicknesses are purposely not given, as the slopes are obscured by talus, while all the beds are dipping 10° north of west.

From a small col above the valley, an important fault running slightly east of north and west of south is well shown, a series of green-coloured shales resting directly against beds higher than the nodular limestone, while hitherto these shales had not been seen. The pass itself was in the marls (No. 4), below which was a massive limestone, and on ascending the slope, the nodular limestone was met with 46 metres above the col, with the nummulite beds resting on it at a far higher level than in the foot-hills, the difference as determined by aneroid being over 120 metres. The summit of the eastern end of Jebel Arras was formed by a limestone with small foraminifera, and a cherty limestone in which fossils were not seen.

Descending the slope, the succession was repeated in reverse order, but lower beds, viz., the shales etc., above-mentioned, were now found in the valley. They consisted of a white flaky marl at the base, above which came a gypseous band and an unctuous yellow clay, these again passing into pink marls and limestone. The yellow clay yielded a number of small but well-preserved Nautili, and a *Nucula*.

Jebel Serrai.

Jebel Arras, owing to faulting, is not very suitable for determining the general succession, which is however well displayed in the outlier of Jebel Serrai on the southern side of Wadi Qena. This hill can be ascended from the front; the thicknesses here recorded have been obtained by aneroid, the succession beginning from above:—

Top.	Metres.
1. Isolated hard limestones, alternating with marls, and cherty beds at the summit	15
2. Nummulitic limestone, similar in all respects to that already described on Jebel Arras, forming a flat plateau on the western side of the hill	
3. Nodular limestone forming a distinct, precipitous, and under-cut cliff all round the hill, about	8
4. Alternating beds of limestones with regular layers of flint, shaly limestones, and oyster-beds low down in the series.	113
5. Alternating cherty and limestone beds with two thick bands at the top, one entirely composed of oysters	73
6. More thickly-bedded limestone with shaly bands, and shaly marls below, together	15
7. Thick-bedded limestone with silicified nodules	—
8. (Not seen in actual cliff). Basal white limestone, weathering pink. This gives a thickness of more than 225 metres, exclusive of the shales which do not appear here.	

At the foot of Jebel Serrai north of the beds marked 7, strata of hard limestone alternating with hard quoit-like nodules of crystalline limestone, appeared from under the pebble-gravels, having an

apparent dip of 35° southwards towards the hill, At the base of the mountain, on the west side, the beds were again dipping at 35°, nearly due south, and consisted of a limestone with close-layered flints with an oyster-limestone below. These beds are precisely similar to some in the main escarpment, the amount of throw of the fault being over 90 metres.

In a valley running south-east toward the back of the mountain, the basal white limestone, weathering pink, is seen dipping 10° west, having in it layers of pink marl and fissile limestone, while above it is a broken and contorted mass of limestone and chert, which has undergone extraordinary crumpling. The dip when seen is west, that is toward the main plateau, the pink limestone being in part cut out.

This pink limestone forms flat plateaux extending along the foot of the range in the direction of El Jir, in the sides of which the lowest shales (termed by the Survey the Esna Shales) crop out in one or two places.

The full sequence and thickness was not determined until the outlier of Abu Had had been examined, but here also faulting tended to obscure the results. Thus, on leaving the Nagateir plain and entering the first foot-hills of Abu Had from the east, it was somewhat surprising to find them consisting of the pink limestones and flinty members of the Eocene, dipping at an angle of 35° to 50° west, while to add to the difficulty, west of these lay a plateau due to the bone-bed, etc., of the Cretaceous. It is therefore evident that at this point there is a fault the throw of which is equal to the whole thickness of the Esna beds, which is, as will be presently shown, over 105 metres. **Jebel Abu Had.**

Lying between the foot-hills and the main cliff is a well-marked Cretaceous plateau, which is capped by the lowest beds of the Esna series, here forming a few isolated yellowish outliers composed of limestones. All round their base the plateau is strewn with small nodules.

The lower beds of the Eocene series are again well displayed at the southern end of Abu Had, the yellow limestones forming the base, with the green shales succeeding them, but broken into two divisions by an upper yellow limestone, underlying looser limestones and shales. The total thickness of these Esna beds up to the top of the shales is at least 105 metres.

Above these follows the basal pink limestone previously mentioned, 15 metres thick, succeeded by the flinty series, which is the principal component of the bold precipices which render Abu Had inaccessible at most points. Where ascended, the summit was formed by nodular limestone containing small irregular flints, so that geologically the

southern end of the range is lower than Jebel Serrai and Jebel Arras, while topographically it is higher than these. In ascending the hill a large fault is crossed over (running parallel to the main escarpment northward and southward), which brings down higher beds of limestone, these standing out from the softer strata like dykes, and dipping at an angle of 70° into the mountain, the dip gradually diminishing towards the plateau at its western foot, but owing to the absence of beds with special characters, the total throw was not determined. (See Section IV, Sketch 1.)

Taking the three sections above described together, we have two marked divisions:—

		Metres.
Serrai Limestone.	Nummulitic limestones ... ... Nodular limestone ... ... Banded flint series	225
Esna Shales.. ...	Pink limestone ... ... Green shales.. ... ... Yellow limestones and Pecten marls ...	122
Total determined thickness of Eocene near Qena...		347

This succession practically supplies the key to the main characters of the Eocene beds round Qena; the following statements are merely questions of distribution. Thus, there has probably also been faulting on the south-western side of Abu Had, as the plateau at its base is no longer formed by Cretaceous beds, but by the pink limestone below the flinty series.

Between Wadi Um Selimat and Wadi Hammama.

Between the divide at the head of Wadi Um Sellimat and the Cretaceous plateau of Hammama which will subsequently be described, the country is of a hummocky description, rising into low hills, composed of the lowest member of the limestone plateau—the pink limestone—this again being underlaid by:

Yellow-green to dull-green shales.
White marly limestone (weathering brownish-pink) and light-coloured marl, alternating.
White limestone and marls, containing abundant *Pectens*, fish-scales, sharks' teeth, and numerous small spines of echinoderms, these in some cases being the main components of the rock. These beds dip normally 2° to the north-west, but near the point where they rest unconformably upon the Cretaceous limestones, dip 3° east.

Here then we have practically the whole succession of beds included under the term Esna Shales, but their thickness is not easily determinable.

When ascending Wadi Qena, Jebel Arras was ascended from the eastern side, the succession being as previously noted, but a series of

blue-grey limestones were found to be closely connected with the nodular limestone, these containing small nummulites, while on the summit was a red and white breccia lying in fragments on the surface.

In following up Wadi Qena, the higher foot-hills lying in front of the main escarpment were found to consist of nodular limestone and red breccia, while as the former was seen to be far higher in the main cliff, it was evident that these hills owed their origin to faulting. This fault, which is clearly shown in many places along the sides of the main escarpment, is a trough-fault (occurring between the main and lower hills), in which the beds are highly tilted. (See Section IV, Sketch 2).

The Esna Shales are not visible in the foothills, but are present in a valley which runs parallel to the escarpment, the pink limestones being also observed above them.

As the northern end of Abu Had is approached, the sandy limestones described under the "Gravels" having been crossed, a breccia of greenish-grey and pink limestone fragments cemented by a hard silico-calcareous cement is met with, behind which rises the long thin western spur of Abu Had, composed of Eocene limestones with flint bands, these showing distinct evidence of trough-faulting similar to that observed in Jebel Arras. The lines of fault are almost due north and south, and are found on both sides of the ridges. On the eastern flank the beds are dipping 60° into the hill, while the fault apparently runs out into Wadi Abu Had, which forms a great horse-shoe. (See Section V.)

If the outlier of Abu Had be considered as a whole, apart from faulting, the beds are seen to be dipping normally at an angle of 4° northward, with the result that the flinty series, which is close to the summit in southern Abu Had, is here at a lower level, and is overlaid by marly limestones. But, although the conditions in the main plateau are thus comparatively simple, the lower isolated hills which rise out of the gravels of Wadi Abu Had show very complex conditions. To the north-east are low foot-hills in which faulting is very marked. Approaching from the west, the beds are seen to be dipping eastward at an angle of 65°, gradually becoming vertical, and changing direction of strike, as shown by the harder beds. On the north there is an inversion of the dip, the beds being tilted east at a high angle. The dip changes so frequently as to suggest the probability that we are here dealing with a faulted dome, the centre of which is composed of pink limestone and Esna Shales. (See Section VI.)

Faulting is, indeed, very prevalent all round the edges of Abu Had, which is evidently due in the first instance to this action, the higher banded flinty beds having been let down, both to the east and south, against the softer white limestones of the Esna shales (see Section IV, Sketch 1). The latter have been more rapidly worn away, with the result that the flinty series now forms vertical escarpments enclosing the greater part of the valley. At the southern edge, the nodular beds have been let down to the level of the flinty series, giving rise to a secondary ridge.

A low knoll* in the centre of the valley is of special interest, as it is found to be due to the intrusion of a small knob of hornblende-andesite (changing to a more doleritic rock on the outside) into the Eocene limestone, the latter having in consequence undergone distinct recrystallization. Red garnets and epidote have been formed near the junction, the latter being in such quantity as to produce an epidote-rock. On leaving Wadi Abu Had and going eastward, a yellow hill is seen rising out of the gravel plateau, which is also formed of much-folded Eocene limestones, with shales containing ferruginous nodules at the base, while continuing in the same direction, after passing between the north-eastern end of the main Abu Had range and the prominent outlier of Jebel Nagateir, a new group of foot-hills is entered.

In the outlier itself the beds are tilted westward, at a high angle, Esna shales appearing at the base, these again being capped by the pink limestone, the flinty series, and finally very prominent, dark, nodular beds. In the main chain also the Esna shales again appear at the base, but in between it and the outlier are a number of ridges of Nubian sandstone, immediately underlying crushed pink limestone with flint, the sandstone becoming towards the Fatiri plain highly ferruginous.

Summary—1. It will thus be seen that the Eocene Beds near Wadi Qena present fairly uniform lithological characters, being divisible into two principal groups—

I.—The Serrai Limestones, containing small nummulites of Londinian type at the summit, and further characterized by the prevalence of nodular beds, and the abundance of parallel bands of flints, having a thickness of at least 225 metres.

II.—The Esna Shales, consisting of green shales above, and very light-coloured marls and limestones below, the former in places containing abundant nautili, and the latter marked at the base by a

*One of the flints at this locality contained the impression of a large fish, in which the head was unfortunately absent, but the vertebral portions are well displayed.

species of small *Pecten*, the two series together exceeding 120 metres in thickness.

2. Where these Eocene beds have given rise to steep cliffs or now exist in the form of outliers separate from the main plateau, they have, in all the cases noted, been found to be in intimate connection with lines of faulting, which are apparently the direct causes of these escarpments.

3. It is also interesting to note that igneous rock of an andesitic nature has been intruded into the Eocene rocks, the latter having undergone contact metamorphism.

As regards the practical aspect of these beds, they are at present used for the following purposes: Limestone is quarried on the sides of El Jir to be burnt for lime. In addition the Esna shales and limestone often contain a good deal of salt, which is dug by the Arabs for their own requirements, but not worked by them on a commercial scale. Many of these diggings were noted at the base of Serrai. The Esna shales in addition contain a small percentage of nitrates and are used by the natives to spread over their fields. W.F.H. & T.B.

It should be remarked that the white limestone weathering pink is identical with the rock in which the Tombs of the Kings have been cut at Thebes, and indeed has apparently been utilized for a similar purpose in the cliffs abutting on the river north of Qena.

Another interesting occurrence in this region is the beautiful breccia, composed of fragments of a white and deeply-coloured pink limestone cemented together, which is already well known under the name of "Brocatelli." It has been assumed* that it forms part of a fault-breccia, and in not a few instances this seems highly probable, as for example, where it is well developed near the fault bounding the western side of the north-west spur of Abu Had, or along the foot of the El Jir and Serrai outliers. On the other hand, the occurrence of a similar rock on the summit of Jebel Arras suggests that this generalization may not be absolute.

Palæontological Position of the Eocene Strata near Qena.—It is a remarkable fact that, even to the most recent writers, the area immediately to the east of Qena is in its geological features practically an unknown region. Thus on examining Fraas' map,† great surprise was felt to find that the very hill which in this memoir has been taken as the typical example of the Eocene series, Jebel el Serrai, had

* e.g. Fraas *loc. cit.*, p. 7.
† *Loc. cit.*, p. 23.

been there included in the Cretaceous (Campanian), while the Eocene was restricted to the the left bank of the Nile. Similarly, Blanckenhorn, in his paper on the Cretaceous, discussed subsequently (p. 182), states that in the middle and lower part of Wadi Qena the Nubian Sandstone is directly overlaid by the fossil-bearing Senonian, a statement which must be either based on a misapprehension of the field reports, or on the fact that Figari found *Mosasaurus* remains in a bore near Qena. Fraas crossed the Um Kerenat range to the south, obtaining Campanian fossils at that locality, and judged from the apparent agreement in the form of the hills that Serrai was of similar geological structure. He notes a striking distinction between the vertically-rising cliff on the other side of the Nile, which is well-known to be Lower Eocene. The difference between the two sides is certainly, as stated, a striking one, but it is not a contrast between Eocene strata in the western cliff, and a Cretaceous series on the eastern side, but between a continuous Eocene escarpment on the left flank of the valley, and a broken system of outliers, at first purely Eocene, as in Abu Had and Serrai, and afterwards Eocene in the higher summits and Cretaceous at the base, (there, well developed and giving rise to fine outlines), bordering the right bank of the cultivation.

Blanckenhorn, who, as before stated, possessed exceptional opportunities for examining collections from many sources, and has since been able to look up the literature of the subject in Berlin, has compiled the Eocene results in a paper* which is of use as bringing together the palæontological conclusions of various writers as well as his own into a compact whole, and is a helpful basis of comparison. The beds represented in the neighbourhood of Wadi Qena and probably throughout the area under consideration belong to the Lower Eocene, which in the above paper is also termed Suessonian.

The Lower Eocene is classified by him into three divisions, viz.,

Upper Libyan,		Upper Libyan,
Lower Libyan,	corresponding to our	Lower Libyan,
Kurkur-stufe,		Esna Series.

Lower Suessonian or *Esna Series*.—Lithologically the strata to the east of Qena are sharply divided into two groups—

(1) Limestones, termed here the Serrai limestones, and

NOTE.—It is somewhat to be regretted that the term Londinian should be rejected for this division, as the Middle and Lower Eocene would then be represented by two of the most prominent cities built on these strata, viz., Paris and London, but in this matter of naming priority and general usage must be followed, and we have not at present the opportunity of looking up this subject.

* (Blanckenhorn, "Neues zur Geologie une Paläontologie Aegyptens, II. Das Palœogen A. Das Eocän," zeitschr, d. Deutsch. geolog. Gesellschaft, Jahrg, 1900. pp. 403-479).

(2) Shales, marls, etc., the Esna Series, this name having been first adopted by Barron and Beadnell for this well-marked set of beds. Blanckenhorn states that the distribution of the oldest Eocene series is not great, being chiefly found in the Kurkur Oasis, and possibly in Kharga, and represented by a thin deeper-water series in the neighbourhood of Thebes. Far from there being this limitation, they are, of the widest distribution, having been shown by Beadnell to be a conspicuous feature in Farafra (as they should be according to Mayer-Eymar's hypothesis mentioned by Blanckenhorn) and on the left bank of the Nile (Esna, etc.). Ball has also mapped their full extension in Kharga, while Barron has noted their distribution on the right bank of the Nile, south of the area embraced by this memoir. Thus working from west to east, they are everywhere found to be well developed under the Eocene limestones.

The Wadi Qena facies, though very poor in fossils, except in one layer of green shales, nevertheless in all probability belongs to the deeper-sea type recorded by Fourtau and well worked out by Delanoüe* as long ago as 1868, as it contains an abundant fauna of small nautili, as well as *Nucula* and *Leda*, but unfortunately is lacking in the numerous other genera recorded from Thebes. The lowest 31 metres at the latter locality is evidently only the upper part of the Esna beds, where they can be well seen in the neighbourhood of the temple of Deir el Bahari and for all that is known to the contrary, may be quite as thick as in Abu Had, where they are over 122 metres.

The Esna Shales thus are of great importance, and are conformable with certain marls and marly limestones, one of which immediately overlying the unconformity near Wadi Hammama has given rise to a difference among palæontologists. Bullen-Newton† described a *Pecten* from this soft cream-coloured chalky rock, etc. as bearing a true Eocene facies, being related to *P. reconditus* (Solander), and *P. carinatus* of J. de C. Sowerby, the details of the identification being then given, and the form being named *Pecten Mayer-Eymari*. Blanckenhorn, however, differs *in toto* from Newton on this point, considering that they are identical with the Campanian and Danian *Pecten Farafrensis*, and that Newton's species must be withdrawn. The adoption of the latter position would involve us in this difficulty, that the unconformity mentioned later would be Inter-Cretaceous, i.e., between Danian and Campanian, or Campanian and Campanian, while the highest Cretaceous beds

**Bull. Soc. Géol. France*, (3), XXVII, 1900, p. 481. *Comptes rendus* 1868, LXXVII, pp. 704-707.

† "Notes on Lower Tertiary Shells from Egypt," *Geol. Mag.* Dec., 1890, No. 414, N.S., Sec. IV, vol. V, No. XII, pp. 535-536.

would be absolutely conformable with the Esna Series! It must be confessed that, rather than adopt this radical change of view, it seems preferable to consider that Blanckenhorn himself is in error on this point.

Lower Libyan Series.—Owing to the poverty of the fossil contents in the thick series of limestones occurring in the hills bordering Wadi Qena, and the fact that the fauna obtained from these beds has not yet been fully analyzed, it is difficult at present to draw a sharp line of demarcation between the Upper and Lower Libyan. From the lithological point of view, if the limestones and clays without flints were taken as Lower Libyan, and the "Weisse Kalke mit grossen Kieselconcretionen" (see Blanckenhorn's table) as Upper Libyan, then practically the whole series would be Upper Libyan. On the other hand, if the Lower Libyan be regarded as 200 metres thick, as shown in the above table, then the whole would be practically Lower Libyan. Unfortunately, that widely distributed and characteristic form *Lucina thebaica*, though abundant near Qena itself, is not found in the hills to the east, and characteristic small nummulites (of the *N. variolaria* type) are only present near the summit of the hills, usually in the uppermost 30 metres. As these uppermost beds also contain numerous turritellæ and a small multicostate oyster they are provisionally taken as the representatives of the Upper Libyan, leaving 200 metres of flint-banded limestones to the Lower Libyan. These beds are, however, only a day's journey from Qena, so that further palæontological research to fix the limits of these two sub-divisions can easily be carried out.

It may be here stated that these sub-divisions are probably the same throughout the area, denudation having apparently been carried down to the uppermost layers of the nodular and flint-bearing series, when their hardness and uniformity of structure led to the formation of the level plateaux so familiar to all visitors to Egypt.

B.—The Faulted Eocene Areas south of lat. 27° N.—While on the western side of the Red Sea Hills the Eocene beds are more or less connected, on the eastern slope they consist of a series of widely separated outliers, owing their preservation to the action of faults, and generally having their beds tilted at high angles, so that the plateau structure disappears.

The present memoir deals with several of these; but other limestone ridges were visible south of the Qena-Qosseir road, which must owe their origin to the same cause. The principal exposures in this area are the important range of Jebel Duwi, the faulted synclines of Nakheil, Wadi Safaja, and Um Tagher, and a small exposure on both sides of Wadi Hamrawein.

In his recent publication Prof. E. Fraas,* has recognized the existence of the 100-metre thick beds of the Middle Libyan or Suessonian containing abundant flints and overlying the Cretaceous beds with *Ostrea Villei.* He remarks that fossils are very rare, his finds being restricted to the characteristic casts of *Lucina thebaica.*

Jebel Duwi Range.

The Eocene strata give rise to this important topographical feature on the eastern side of the Red Sea range. It† forms a bold white cliff facing southward, visible from the centre of the Red Sea Hills, while to the north it runs sharply to earth with a dip-slope of from 15° to 20°, this being also broken by a secondary ridge, the result of faulting.

The whole range is the result of complicated folding and strike-faulting (for the discussion of which see p. 209). The Eocene strata lie in succession against Nubian Sandstone, metamorphic rocks, and granite (at Jebel Hamrawein). To the west of Jebel Hamrawein, the junction of the Tertiary beds with the metamorphic rocks is almost a straight line. At this point the Tertiary strata are only present as low yellow ridges, but to the west of Wadi Sodmein rise into a prominent white cliff consisting of Eocene nodular limestone, with scattered, rounded flints. Still further to the west the range is breached by the cañon-like gorge of Wadi Saga, where the Tertiary flinty series dips at an angle of over 8° north-west. The fault is still present, but not so marked as in previous cases, owing to the absence of a visible junction between the Tertiary, Nubian, and metamorphic strata. The cliffs of the gorge itself showed the flinty series well (one flint layer being over 1 metre thick), while nodular beds were also frequent. In addition the beds were folded, and in places, especially near the centre of the ravine, much trough-faulted. At the northern end of the range the beds were dipping 10° southward, there being probably also faulting to the north-west, where the strata in a ridge separated from the main range were tilted south-east at an angle of 45°. On the southern side, the Tertiary beds, here nearly horizontal, were seen to be directly faulted against the metamorphic rocks, so that prominent faulting has passed from the northern to the southern side of the hills. The Esna series of the Eocene were not met with on the north side of the range.

On the southern side, the Eocene succession is well seen in the steep cliff previously mentioned. Briefly summarised it is as follows:—

Top.

1. Limestone with flints, very thick, the quantity and size of the flints varying in places; the bands were continuous.

* *Loc. cit.*, p. 28. † See Plate III.

2. White limestone weathering pink.
3. Upper Esna Shales—Friable white limestone with brown paper-shales at the base.
4. Marly limestone alternating with beds of fissile marl.
5. Greyish-green marly shales of the Lower Esna series.

There are few fossils in the above beds.

6. Marly limestone with *Pecten*, *Nucula*, etc.

The Eocene strata rest unconformably on the underlying Cretaceous beds, the former dipping at an angle of 8° in an east of north direction, while the latter show a dip of 30° in the same direction about a quarter of a kilometre from the junction.

The Qena-Qosseir road cuts through this range near Bir el Beida, along a line of dip-fault, the strata otherwise being similar on both sides, but to the east of the road, the ridge suddenly expands into a plateau, which has been let down against the diabase on the east by a dip-fault, and on the north by a strike-fault. The main ridge is indeed still separated from this plateau by a line of fracture parallel to the Duwi range, giving rise to a small plain from which the drainage is discharged through a narrow gorge into the principal valley.

Further west, on the edge of the plateau, steeply inclined beds were seen, dipping about 45° to the cliff, and bringing up the Esna shales. It is probable that several parallel faults occur here in close proximity. On the other side of the valley, between the crest and the plateau, beds were seen dipping about 10° in a westerly direction towards the cliff. There is therefore possibly a fault of opposite downthrow having direction about 10° west of north (see Section VII.) These faults coincide with the boundary of the igneous rock on the other side of the plain.

To the north-east of Bir Nakheil rises a conspicuous hill which shows all the sedimentary series from the base of the Nubian Sandstone to and including the Eocene, the latter resting as a cap on the summit of a plateau of Cretaceous limestone. These beds are dipping steeply westward and evidently form part of a distinct, though probably faulted syncline, the Esna shales at the base cropping out to the east, while at the western end only the flinty limestones were noted, the higher portion of the hill being crowned by a nummulitic limestone similar to that on the summits of Arras, Serrai, etc.

This was succeeded by a limestone with flints, the top being crowned by a limestone containing a small multicostate oyster and many well preserved turritellæ. (See Section VIII.) W.F.H. & T.B.

*Eocene of Wadi Hamrawein.**—A little to the south-east of the point where Wadi Hamrawein leaves the igneous ranges, there are a couple

*See Plate III.

of limestone hills let down against the diabase by a strike-fault, the strata dipping 30° south-west towards the line of dislocation. The hills are again fractured by two dip-faults, which carry the northernmost ridge forward, this bringing up the Cretaceous limestones opposite younger beds on the other, or northern side. The strata found in this area are—

(1) Flinty series.

(2) Pink limestone, and

(3) Esna Shales, around their bases being coral limestones of Pleistocene age.

To the north, between the above valley and Wadi Abu Hamra, two other exposures of Eocene limestone are present, the lower beds being covered by beach deposits.

*Confluence of Wadi Safaja and Wadi Wasif.**—The Eocene beds here consist of the following members from above downwards:—

Top.

1. Nodular limestones.
2. Limestones with flints.
3. White limestone, weathering pink,
4. Whitish marly beds—Upper Esna beds. ⎫
5. Marly limestone, weathering pink. ⎬ Esna Beds.
6. Greenish shales—Lower Esna beds. ⎪
7. White marly limestone with *Pectens*. ⎭

Bottom.

The beds at the junction of the wadis are tilted at an angle of 20° to the west, being thrown down by a north and south fault. Another patch a little to the west is thrown down by an east and west fault against Nubian Sandstone (see Section IX). The limestones form a ridge running in a north and south direction, and dip towards the west at an angle of 30° at the northern end.

At the extreme north end of the syncline in which these beds lie, they bend round towards the west, and are thrown down against the Esna beds by an east-and-west fault, the dip of the beds on the downthrow side being 45° to the south.

On the west of the north-and-south fault, at the northern end of the syncline, the limestones are overlaid unconformably by a series of cherty conglomerates and gritty sandstones previously described (p. 124).

The Esna beds do not differ in character from those already examined in other places, except in one respect, viz., that there is a marked thinning of the middle limestone. Although there were no sections to show the dip of these beds in the main mass, still it must be about 30° west, as the overlying limestone dips at that angle, and the two are always conformable.

* See Plate IV.

To the north-west of Wadi Um Tagher, between Jebel Um Tagher and the gorge of Wadi Barud, the Esna beds agree in all particulars with those mentioned above. Here, however, the Eocene limestone has been almost entirely removed, except for one small cap on the central hill. They are faulted down to the west against the granite, having a dip of 20°.

From the above descriptions it will be seen that the Eocene strata on both sides of the Red Sea Hills are remarkably uniform in character, though the shaly beds of the Esna series appear to have somewhat diminished in thickness on the eastern side, and the conclusion is that the Eocene beds were laid down over the whole of the desert lying between the Eocene areas described.

Eocene bordering the Red Sea Hills.—Immediately on leaving the granite area east of Jebel Dokhan on the road to Bir Mellaha, an exposure of Eocene rocks is met with, consisting of—

(1) Flinty series.
(2) Pink Limestone, and
(3) Upper Esna Shales.

These are evidently faulted down to the east, as the beds are tilted to the west at an angle of 15°, while similar areas were noted in the distance lying against the igneous foot-hills, both on the west of the Mellaha road, and also further to the north beyond Jebel Kufra. The Eocene beds are also found close to the Red Sea Hills on the sides of Wadi Dara, consisting of (*a*) the flinty series, (*b*) the pink limestone, (*c*) Esna Shales of a more sandy nature than usual, the whole tilted at

Wadi Dara

an angle of 30° to the north-east. Portions of the pink limestone were completely altered to gypsum, while at the top of the Esna series occurs a thin bed of impure ferruginous limestone full of casts of turritella, etc., as well as pelecypoda. There is also a thin bed of marl containing the remains of ostrea much broken up. This ridge has been faulted down against the Nubian Sandstone along a north-west and south-east line, *i.e.* parallel to the line of the Gulf of Suez, but hading towards the Red Sea Hills, thus suggesting a trough-fault.

Two kilometres further down the valley a steep ridge of the Eocene flinty series is present, tilted at an angle of from 40° to 60° to the north-east. The Esna Shales and Cretaceous limestones in this exposure are covered by later deposits, but the Nubian Sandstone crops out at the base of the cliff. The ridge itself has also been thrown down against the Nubian Sandstone, which appears in the plain further to the north-east. T.B.

C.—Eocene range parallel to the Red Sea, north of 27° N.—On crossing from Dokhan to Ras Jemsa and Jebel Zeit, the great plain having been traversed, a low limestone ridge is entered, which is seen to extend in a north-west direction and to be cut through at right angles by all the main valleys draining from the Red Sea Hills.* Judging from the previous work on these rocks, the beds composing these hills have been a puzzle to those who have explored them.

Zittel, basing himself on Schweinfurth's collection, in his map describes them as belonging to the Upper Cretaceous with *Ostrea larva* and *Exogyra vesicularis;* while Mitchell, in his paper on the Petroleum, also colours them definitely as Upper Cretaceous. Schweinfurth himself, however, clearly recognized that they belong in part to the Nummulitic series in his paper published in "Il Exploratore," which brings together the results of his desert work in a masterly manner, and in which he distinctly speaks of the "altipiano nummulitico" in connection with the range.

The discovery of the line of demarcation between the Cretaceous and Eocene in Wadi Hammama, has enabled the Survey to approach this question with new light, and it can now be stated that the main mass of the chain is Eocene, the strata represented in it being the whole of the Esna beds with the Pecten marls at the base, and the Serrai series as far as, and including the limestone with bands of flint, the Cretaceous, though very interesting, being of quite secondary topographical importance. The Eocene at this point is, lithologically, a repetition of that described under the first two headings, and palæontologically did not appear to be very rich by contrast with the Cretaceous limestone underlying it. To the north, on the level of Jebel Zeit, these strata form part of a completed syncline, but further south, near Bir Mellaha, dip at an angle of 12° to the south-west being probably faulted at this point, though full evidence for the latter is wanting, the pebble-covered plain or greenish marls with large oysters extending to the foot of the limestone (see Section I). The limestone range terminates with a prominient outlier a little south of Bir Abu Nakhla. To the south the range gradually becomes lower, the lower beds passing under the ground, until it stops abruptly near the road which leads from Jebel Dokhan to Wadi 'Esh, in highly tilted strata due to a fault running in an east-and-west direction.

Eocene fossils appear to be very rare in these beds, except at the base, where specimens of *Pecten* appear in quantity in the marls. R.B. Newton has described these under the name of *Pecten Mayer-*

*See Plates V and VI.

Eymari, and referred them to the Libyan series, a conclusion in agreement with the general stratigraphical position of these rocks. These Pecten Marls form the base of the series throughout the Mellaha-Dib limestone range, which embraces all the Libyan up to and including the flint-banded beds, that is, all the Esna beds, and the greater part of the Serrai Limestones.

It is not surprising, therefore, to find that Blanckenhorn in his compilation of the Eocene should have followed in the steps of previous writers in stating that "to the east of the Red Sea Hills north of 27° N. lat., curiously enough no Eocene appears to exist, the Cretaceous beds being directly overlaid by Miocene or younger coral-reefs. This region, near the Red Sea to the west of Jebel Zeit and the Jubal Straits, must at that time have been dry land." It may be freely admitted that in the copy sent to the Survey the writer has made a complete recantation, by adding a written note stating that "only the Lower Libyan beds were observed directly overlying the Campanian" (*loc. cit.*, p. 405). The same confusion of ideas marks his remarks on p. 412, where the writer calls for the withdrawal of *Pecten Mayer-Eymari*, a withdrawal which cannot be accepted, unless subsequent visitors to these rocks can show that the pectens of the marls at the base of the Eocene series have like the *Gryphæa vesicularis* mentioned later (p. 190), been derived from the worn-down Cretaceous rocks.

The only point of difference that can be conceded as to the Eocene in this district is that the Turritella beds of the Upper Libyan have not been noted here, and the thickness of the whole series is much less than near Qena, though still exceeding a hundred metres. W.F.H.

Conclusion.—The main conclusion from a study of the Eocene rocks in this area is that these extended throughout the district with practically the same characteristics, their present distribution being due to great dislocations assisted by denudation.

Rocks of Doubtful Age.—About 8 kilometres east of north of the place where Wadi el Mogher leaves the hills, and lying in the plain east of the gravel plateau which separates the drainages of this wadi and that of Abu Garia, there occur some low ridges of hard crystalline limestone, weathering pink, much crushed, and containing numerous black streaks.

The rocks, when fractured, are of a grey tint, and when struck sharply with the hammer give off a strong smell of petroleum. These have evidently at one time been overlaid by the gravels previously described. From the point where they were first examined they could

be traced for 3 kilometres to the south, where they were capped by clayey beds differing widely from any of the beach deposits, but closely resembling the Esna shales. That these are not beach deposits seems to be borne out by the fact, that behind their escarpment on the south side is a lower plateau consisting entirely of raised beach materials. It thus follows, if these clays be Esna shales, then the metamorphosed limestone must be of lower Esna or Cretaceous age.

Section V.—CRETACEOUS LIMESTONES, ETC.

Although Cretaceous beds have long been known to exist in the Arabian Desert, details regarding them were till recently very scarce, the most complete account which had yet appeared, that of Zittel* only dealing very briefly with the characters and distribution of these occurrences. As was naturally to be expected, the first discovery of Cretaceous strata was made in the Nile Valley itself, Figari Bey† describing marls, clays, and limestones as overlying the Nubian Sandstone between Siloë and Edfu. The succession as given by him for the two banks of the Nile is as follows, beginning from above.

Top.

1. Compact, ash-grey limestone in great nodules, embedded in an impure shelly limestone with numerous *Ostrea larva*, *Ostrea Renoui*, *O. Forgemolli* and *O. Aucapitainei*.

   Note.—The names of the fossils are the corrected ones given by Zittel in the above-mentioned work. Figari Bey, having identified every species incorrectly, had arrived at the conclusion that these beds were of Lower and Middle Cretaceous age, whereas Zittel points out that they are very closely related to the Algerian Campanian and Dordonian.

2. Ash-grey, sandy breccia with remains of bones, fish-scales and shell-fragments. The cement is a ferruginous clay.
3. Yellow, marly sandstone, alternating with a yellow, sandy, calcareous marl, the first containing large stems of silicified dicotyledons.
4. At the base ferruginous, compact, sandstone containing silicified wood, and spherical sandstone concretions, in addition also ash-grey or greenish paper-shales, which contain salt, gypsum, and brick-red ochreous nodules.

Figari Bey also undertook two borings, both of which appear to have been in or to have reached the Cretaceous, the first at Redesia, near Edfu, being almost entirely in clays and sandstone, while the other, sunk in Wadi Qena, reached ash-grey clays containing large bones and a lower jaw of *Mosasaurus Mosensis*.

* *Beiträge zur Geologie, etc., Palæontologie, etc., Libyschen Wüste*, pp. LXXVI-LXXXII.
† L. c. bd. I. S. 23-25.

In 1882, Schweinfurth (results embodied in Zittel's work) threw further light on the distribution of the Cretaceous limestones, as he found the hillocks near El Chaui to consist of a flaky sandstone and thin marly layers, covered by a limestone 2 metres thick, containing innumerable, often well preserved examples of *Ostrea Aucapitainei*, Coq., forming a regular oyster breccia, and enclosing specimens of the larger *O. Forgemolli*. This oyster breccia, according to Zittel, represents the bed No. 1 in Figari Bey's section.

Zittel also concludes that above these beds should follow a complex of ash-grey or green paper-shales and a white limestone, while Schweinfurth did actually find these paper-shales at Esna forming the base of the Eocene plateau. These, as a matter of fact, are the Esna Shales, in which neither Zittel nor Schweinfurth obtained any fossils, but Delanoüe * found a number in the green clays near Thebes, and agrees with the Survey in regarding these as Lower Eocene.

This was the state of knowledge when in the beginning of 1897 Barron commenced a geological examination of the country between Qena and Esna, and showed that the bone-bed No. 2 mentioned by Figari Bey was in reality phosphatic, and possibly of commercial value. Owing, however, to the faulted nature of the ground, good sections were not displayed.

During the joint expedition from Qena to Jidami the discovery of the Ptychoceras beds overlying the bone-bed enabled the succession to be put on a satisfactory basis, and supplied the key, not only to the interpretation of the Cretaceous strata east of Qena, but also of those occurring near Qosseir, and on the eastern side of the Red Sea Hills.

The collections made by the writers were forwarded to Cairo, where they were examined by the Palæontologist to the Survey, Dr. Blanckenhorn, who has just published his views on this subject.† His palæontological results are of general interest and serve as helpful guides to the closer division of the Cretaceous, but, as far as detailed statements regarding the Eastern Desert are concerned, most that is novel in his work is founded on the writers' collections and notes or on those of Dr. Schweinfurth. Owing to his writing about a district with which he has no personal acquaintance, he has fallen into errors which it is necessary to correct before proceeding further. Thus it is stated that fossil-bearing Senonian overlies the Nubian Sandstone in the middle and lower part of Wadi Qena, whereas a perusal of the present memoir will show that in the latter only Eocene beds and Valley limestones

* *Comptes rendus 1868*, vol. 67, S. 704-706.

† *Zeitschr. d. Deutsch. geolog. Gesellschaft Jahr.* 1900, pp. 21-47.

and gravels are exposed, and the southern Senonian dies out in the plains long before they join Wadi Qena to the north. In the same list of localities, Wadi Hammamat, which is on the southern Qena-Qosseir road, is substituted for Wadi Hammâma, the locality from whence the important Cretaceous exposure is described in the subsequent pages. On page 41, Bir el Beida and Bir el Inglizi, which are different names for the same well, are spoken of as though they were different collecting grounds. The paper continues "*Es wurden hier gesammelt Gryphœa vesicularis,*" etc., no statement being appended that the writers of this memoir were the collectors in all the cases mentioned.

In a note on the same page it is further stated that above the limestone of Wadi Dib with *Gryphœa vesicularis*, etc., and under the Eocene "Tafle" marls follow, according to Mitchell (date of work wrongly given as 1847, really 1887), sandstone, etc.

No one would imagine from this note, that Mitchell himself expressly denied the existence of Eocene beds in this region at all, which is a new point brought out by the Survey, and further it may here be stated that the term "Tafla" was a temporary field-name used by the officers of the Geological Survey, which is replaced in the Survey memoirs by the term "Esna Shales," derived from the locality where these beds are typically developed. Again, on the same page, it would appear that the phosphate beds occur, "according to Barron and Hume's researches" *only* on the west side of the Arabian coast-range on the plateau of Wadi Hammamat (see above) and between Um Tagher and Wadi Safaja. The subsequent report will give sufficient evidence that these are *not* the only records of such occurrences, and further Um Tagher, etc., are not on the west side of the Arabian coast-range.

On page 42, while Fraas' new find at Hegaza between El Geita and Qus is mentioned, Dr. Blanckenhorn has completely ignored the fact that Newton described his new species *Trigonoarca multidentata* from the Survey collection made in this neighbourhood by Barron in the spring of 1897.

Owing to these mistakes, the paper is practically valueless for the Eastern Desert when dealing with localities, while with regard to the differences noted between the Cretaceous exposures on the eastern and western sides of the Red Sea Hills, the writer appears to have adopted the writers' field-report conclusions without further acknowledgment.

The interesting contribution by Prof. E. Fraas,* is as regards the distribution of the Cretaceous open to criticism as previously stated. Similarly, on the east bank of the Nile, he would appear to have

* *Zeits. der Deutsch. Geolog. Gesel. Bd.* 52, *Heft* 4, 1900. See also E. Fraas, *loc. cit.*, p. 30.

regarded the Esna Shales as of Cretaceous age. On the other hand, he recognizes the beautiful development of the *Ostrea Villei* beds near Bir el Inglizi, and marls containing *Ostrea Boucheroni*, which are considered by him to be the boundary between the Santonian and Campanian, being also the first to collect from the Campanian of Um Kerenat, and from the Santonian near El Geita. W.F.H.

The following is the detailed description of the results obtained during the survey of this district:—

These Cretaceous rocks occur on both sides of the Red Sea Hills, in general forming a well-marked subsidiary plateau and in all cases being distinctly unconformable to the overlying Eocene strata south of lat. 27° N. One of these plateaux rises from beneath the Eocene escarpments of Abu Had and Serrai and has been traced from the foot of Jebel Abu Had to the pass between Wadi Hammama and Wadi Um Sellimat, a distance of over 20 kilometres; another forms a low ridge along the foot of Jebel Duwi, and a few outliers occur south of Wadi Safaja; a third has been noted in a small faulted syncline north-west of the confluence of Wadi Safaja and Wadi Wasif; while a fourth occurs in another small syncline to the north-west of Wadi Um Tagher.

Wadi Hammama. — On the western side of the area these strata are composed of the following divisions:—

	Metres.
1. The summit of the plateau is formed by a hard, bluish, crystalline limestone, on whose weathered surface appear abundant specimens of Cretaceous Cephalopoda (including *Ptychoceras* sp., *Anisoceras* sp., and *Baculites syriacus* Conr.), small Gasteropoda, and Pelecypoda (*Protocardia* and *Arctica*) this passing below into a less fossiliferous limestone. Some of the baculites were over 15 centimetres long...	0·45
2. Below this limestone is a lighter and more siliceous variety, very compact and of nodular aspect, in its upper layers containing fine casts of *Ptychoceras*, and alternating with chert beds.	1·20
3. A bone-bed, or more strictly a coprolite-bed, partly siliceous, which on fracturing shows a number of rounded white fragments, fish-teeth, *Lamna* (near *appendiculata*) and *Corax falcatus*, etc. This, about 60 centimetres thick, was separated from another 30-centimetre bed, by a band of siliceous limestone 30 centimetres thick, the lower bone-bed being separated by a green marl 15 centimetres wide from:—	1·35
4. Oyster limestone. This shows at its base an interlacing of raised ridges of the kind so often seen at the junction of clayey and calcareous beds. The limestone itself was crowded with a species of *Ostrea*....	1.20
The bone-bed mentioned here is the same as that in the Wadi Matula and it may be that much of the country to the south of this valley should also be considered Cretaceous. There is, therefore, a very wide extension of this phosphate-bearing bed, and should it prove to be continuous between these two points, the supply of phosphate will be practically inexhaustible.	
5. The base of the cliff is mainly composed of greenish shales with two beds of limestone and flaggy sandstones, 7·5 metres thick, which pass below into carbonaceous shales, having ochreous sandstones at their base, also 7·5 metres thick.	15·00

Unconformity between Cretaceous and Tertiary Strata.—While examining the Cretaceous strata on the plateau above Wadi Hammama, a thin conglomerate containing rolled pebbles of the Ptychoceras limestone was met with, which led us to suspect the existence of an unconformity between the two formations. This was confirmed in the small wadis leading from Wadi Hammama to Wadi Um Sellimat, for there the Cretaceous limestones were seen dipping westward at an angle of 8°, while the Eocene beds dipped towards them at an angle of 3°, the point of junction between the two being marked by a shallow furrow. (See Section X.)

The Cretaceous plateau has been breached by Wadi Hammama where it joins Wadi Gareya; from this point it becomes more and more marked, until at the foot of Jebel Abu Had it forms a vertical cliff over 40 metres high capped by yellow outliers of Esna limestone, the point of junction being marked by a layer of small nodules.

The summit of the plateau is determined by the Ptychoceras limestone, beneath which is a bone-bed and over 30 metres of green shales, but in addition below these is a second bone-bed, containing teeth of *Lamna* and *Corax*, vertebræ, also numerous oysters, and other pelecypoda, thus showing that the green shales are themselves referable to the Cretaceous series. The plateau following the dip-slope of the beds, which is 4°, rapidly sinks into the Nagateir plain to the northward.

Possibly, as the result of faulting, fossil-bearing Cretaceous strata form the surface of a low broken plateau at the foot of the main cliff. The summit of these ridges is in some places crowded with the remains of *Baculites*, poorly preserved. A bone-bed lies immediately under the baculite-layer, containing oysters, teeth of *Lamna* and *Corax*, coprolites over 2·5 centimetres in length, abundant vertebræ, and at the junction with the underlying marls, large bone-fragments, most of them unfortunately in a very brittle condition. The base of the plateau is formed by a striped series of alternating marls and sandstone, and hard ferruginous bands of the latter.

An important fault has been observed in the hills north of the low spur running out from the south end of Abu Had. The ridge itself consists of the white limestone weathering pink, and the flinty members of the Eocene series, which just below the summit dip sharply at an angle of 35° to 50° to the west. On the westward side the geology undergoes a marked change, the bone-beds of the Cretaceous series dipping 4° northward, being on the same level as the Eocene strata above-mentioned. It is therefore evident that at this point there is a decided

fault, with a throw equal to the whole thickness of the Esna beds, *i.e.*, over 120 metres.

Thus the following new facts are specially emphasized here:—

1. There is distinct unconformity between the Cretaceous and Esna beds. This important point has been strongly urged by Beadnell, working in the oases, he showing in the clearest manner that there is distinct unconformity between the Eocene and the Cretaceous, especially in Abu Roash, and in Baharia, while the proofs of overlap from south to north, viz., from Farafra and northward have been given by him in a paper read before the International Geological Congress, Paris, 1900. See also Reports of Farafra and Dakhla Oases, Parts III and IV, Geological Survey Reports, 1899. Further, Ball shows in Kharga that the Esna Shales vary greatly in thickness, and are even absent at many points (See Part II, Geological Survey, Report on Kharga Oasis, 1899).

2. A Ptychoceras limestone forms the summit of the Cretaceous plateau.

3. The bone-bed underlying it is a bed rich in phosphate, and in one case at least, two such phosphate beds occur at different levels.

4. The bed rich in oysters is here below the bone-bed and not above it (as in Figari's section).

Eastern Cretaceous.—Of the Eastern Cretaceous beds little seems to have been known up to the present. The elder Fraas passed through the limestones near Qosseir, but finding no fossils suspected them to be all Tertiary, while Klunzinger found a good series of Cretaceous fossils, already mentioned as having been described by Zittel. It is certainly remarkable that these beds, rich in organic remains, and occurring close to one of the most commonly frequented roads should so long have escaped a more thorough examination.

*Jebel Duwi.** On the eastern side a well-marked Cretaceous escarpment is seen, forming the edge of a secondary plateau at the foot of the Eocene cliff. It was first examined at a point opposite the opening of the Wadi Seyala into the Nubian Sandstone plain. Here the escarpment was composed at the summit of an oyster limestone, similar to that on the western side which underlies the bone-bed, small pieces of the latter being strewn upon the surface. Below this limestone came a hard cherty sandstone, itself underlaid by greyish, marly shales containing three bands of sandy limestones, each about 0·3 metres thick. The base of the escarpment is formed of greenish shales similar to those on the western side.

* See Plate III.

Further to the south-east, the plateau was again examined and was found to consist of the following beds, beginning from above:—

Top.

1. White friable limestones, containing small gastropoda, like turritella.
2. White limestone, partly crystalline, containing numerous casts of a large thick-shelled pelecypod with a prominent umbo, *Trigonoarca multidentata*, with which casts of smaller pelecypoda (*Protocardia biseriata* and *Arctica Barroisi*) were associated.
3. Thick series of grey, partly crystalline, limestones, mainly composed of *Ostrea Villei.*
4. A thin bed of alternating layers of limestone and chert.
5. Bone-bed, containing fragments of bone and vertebræ, teeth of *Lamna* fish spines, and coprolites; a certain amount of silicification has also taken place in the upper third of this bed. 0·45-0·6 metres thick.
6. Thin bed of marl. 15 centimetres thick.
7. Oyster limestone (similar to western type).
8. Shales, as in previous section.

The dip of these beds was 30° east of north, underneath the Eocene strata, which were dipping 8° in the same direction. To the north-west the Cretaceous plateau lowers and finally disappears.

*Cretaceous Beds near Bir Nakheil.**—In the syncline previously mentioned (see page 176) the Cretaceous limestones give rise to a distinct plateau round the base of Jebel Nakheil, while the green shales forming their lower member crop out on the eastern side, giving rise to a plain. The sequence in the Cretaceous cliff is obscured in many places by talus, so that no single continuous section can be obtained. At the top of the escarpment the succession is as follows:—

Top.

1. Bone-bed and chert alternating.
2. Limestone with chert bands.
3. Good coprolite-beds.
4. Good coprolite-beds with gastropod casts.
5. Bone-bed with large bivalves, univalves and Arctica. The bone-beds are here much thicker than had previously been observed, the whole being probably about 10 metres.

Descending the plateau on the other side, the large *Trigonoarca multidentata* was abundant in its lower half. In a gorge the following succession was noted from above:—

Top.		Metres.
	1. Hard bed full of *Trigonoarca multidentata*, with a bed of delicate univalve casts and bivalves at the base	3·00
	2. Poor bone-bed.	0·30
	3. Series of fossiliferous limestones with small bivalves...	3·00
II.	4. Poor bone-bed.	0·30
	5. Chert beds....	0.75
	6. *Ostrea Villei* bed with small oysters above....	1·00

*See Plate III.

Finally, in a gully the layer No. 4 (marked II in the above series) was overlaid in reverse order by:—

		Metres
Top.	1. Second oyster bed.	0·60
	2. Loose bone-bed, yellowish-green and friable.	1·30
	3. Bed with *Ostrea* (possibly like western type).	
	4. Hard crystalline limestone.	
	5. *Trigonoarca* cast bed. Above this the mound was capped by unfossiliferous limestones.	

Wadi Saga. At the western end of the Duwi range,* the Cretaceous beds rise from underneath the Tertiaries forming a low plateau and consisting mainly of bone-beds, and cherty layers, closely associated and alternating, of greater thickness than had previously been observed. They dip at an angle of from 15° to 20° to the south and as the Tertiary dips at 10 degrees in the same direction, the difference probably represents the unconformity already noted in previous cases. Westward of this point Wadi Saga opens out into a plain in which are low ridges curving in a peculiar manner, the existence and direction of these ridges being probably due to a syncline of Tertiary and Cretaceous beds which has been faulted against metamorphic rocks.

The ridges consist of two parallel series, one composed mainly of the Cretaceous bone-beds, in some places dipping at an angle of over 20°, the other of Nubian Sandstone, rising behind the Cretaceous.

Wadi Safaja. The banded, siliceous, Cretaceous limestone occurs as a thin patch capping one or two outlying hills of the Nubian Sandstone series south of Wadi Safaja.

Confluence of Wadi Safaja and Wadi Wasif.†—The Cretaceous limestone is present here in a faulted syncline, and is overlaid by the Eocene strata previously described. In character these beds differ from any of the others previously noted; the thick Exogyra-bed, as well as the large pelecypod-bed are absent, while in their place comes a series of marly limestones, alternating with others of a more sandy nature. This evidently points to a more littoral facies for this formation.

Among these marly and sandy beds is a Baculite-bed, which is one mass of these fossils, but also contains *Lima* and other pelecypoda.

The following is a section measured from the bone-bed as far up as overlying debris permitted:—

	Metres thick.
1. Bone-bed No. 1, containing numerous fish-teeth, spines, and coprolites	1·0
2. Flinty bed, containing silicified phosphatic coprolites..	1·0
3. Blue siliceous limestone, in all probability the same as the Ptychoceras limestone.....	0·3
4. Bone-bed No. 2, character same as No. 1.	2·5
5. Marly limestone and marls.	7·7
6. Baculite limestone, with *Lima*, etc.	1·0

* Plate III. † Plate IV.

Above these followed more marly limestones, much obscured by debris. These beds are practically horizontal.

The relation between the Lower Esna limestones and these marly limestones could not be determined, on account of the absence of good clear sections, so that in this case the unconformity, if present, was not so marked as in the Duwi range.

In the syncline north-west of Wadi Um Tagher, the Cretaceous rocks conform in every way to the description of those in the syncline near Wadi Safaja. They here underlie the Esna beds, dipping at an angle of nearly 20° W. The beds have been reduplicated by small local faults.

In the coast-plain extending south of Wadi Safaja is a long strip of buff-coloured gypseous beds, which in all cases conformably overlie the Nubian Sandstone where present, and underlie the beach deposits. They have been undoubtedly Cretaceous limestones (with or without the Lower Esna limestone) which have undergone chemical change into gypsum.

One kilometre north of Wadi Barud, and three from where the Wadi enters the plain there occurs another exposure of gypsum. The relation of this rock to the beach deposits is the same as that of the floor of the sea to the beds forming on it. Wherever these are seen in a section, the junction is unconformable, and in many cases the gypsum rises through the beach deposits like an island in the sea. This suggests the idea that the beach deposits at first covered the gypsum, but as the land rose, the former were removed, leaving the latter, which, on account of its porous nature, withstands denudation much better than a harder rock. The fact of the gypsum hills running up to 183 metres, and gradually descending to about 31 metres above the sea, seems to support the view that the greatest height of these hills would be also that of the raised beach. The problem of the formation of the gypsum is dealt with in detail later. That it has taken place under the sea seems probable, as it is difficult to account for its invariable association, wherever present, with raised beaches, if of sub-aerial origin. It is a noteworthy fact, that any limestone outside the area of the raised beach is unaltered. T.B. & W.F.H.

Strata of Cretaceous age have long been known to exist near the western shores of the Red Sea, Dr. Schweinfurth having described white chalk-like rocks with *Gryphaea vesicularis* and *Ostrea serrata* from the low ranges running parallel to the Red Sea Hills. Some additional facts have been obtained with regard to their nature and distribution during the present survey. Thus near Bir Mellaha, close to the gap which pierces the limestone at this point, flint-bearing

beds are exposed, which contain small *Natica*,* *Nerinœa*, *Scalaria* and other gasteropoda in abundance, also *Protocardia*, *Arctica*, and an ammonite, *Schlœnbachia*, aff. *varians*; various oysters, (*Ostrea Lyonsi*) are numerous in the upper beds, these being succeeded by typical pecten marls of the Esna series, though the unconformity previously noted is not apparent in this case.

The Cretaceous limestones form the base on the eastern flank of the Mellaha limestone hills, lying between the Eocene beds and the Nubian Sandstone, the latter by its weathering having given rise to the valley separating them from Jebel 'Esh.

The Cretaceous fauna appears to have undergone a change, as *Gryphœa vesicularis* and a *Plicatula* were here met with for the first time by the writers. The limestone hills were again examined at the northern end of the Mellaha range, opposite Wadi Dib, the Cretaceous limestone running all round the base (only about 3 metres being visible), andconsisting at the summit of marly limestones full of *Gryphœa vesicularis* and *Plicatula spinosa.* Immediately above these follows the pecten marl of the Esna series, containing at one spot a derived *Gryphaea.*

Below the Plicatula marls are alternations of limestone with flint-bands, and bone-beds containing small fish-teeth, vertebræ, etc., in parts apparently replaced by a stratum of bivalve casts.

Followed south towards Abu Sha'ar, these beds gradually become lower and lower, until they form the floor of the plain, the Esna limestone following suit. A little to the south of the entrance to Wadi 'Esh the Cretaceous and Eocene limestones are cut off by a fault which lets down the sedimentary beds against the igneous rocks.

Wadi Dara. A small exposure of Cretaceous limestone occurs at the base of a Miocene hill on the south side of Wadi Dara, and is probably of Senonian age, *Gryphaea vesicularis* being found in it. Bone-fragments are also present in the *Gryphaea* beds.

Although these Cretaceous strata have been less closely examined than those previously described, sufficient has been stated to show that lithologically they belong to a type similar in many respects to that occurring near Qena and Qosseir respectively, though palæontologically marked differences are observed.

* These have not yet been specifically determined, the present names are only those given provisionally in the field.

NOTE.—There is no question here that the Pecten Marls are above the *Gryphœa vesicularis* beds. This statement is made here because Dr. Blanckenborn quotes Dr. Schweinfurth in support of the opposite view. There is little doubt that the latter referred to marly beds of the Nubian series as being below the *Gryphœa* beds.

Thus, the following points of agreement may be noted, first, the abundance and importance of the bone-beds in all three cases, the existence of flint-bands and the great development of oyster beds.

On the other hand, *Ptychoceras*, *Anisoceras* and *Heteroceras*, are only frequent in the Hammama limestones: at Duwi, on the contrary, *Ostrea Villei* and *Trigonoarca multidentata* may be obtained by thousands, and large nautili are locally in great quantity, but not a single *Ptychoceras*, etc., was found.

Finally, at Mellaha, while *Gryphæa vesicularis* and *Plicatula spinosa* are met with in almost every section, the genera previously mentioned are, if not entirely absent, at least very rare.

The contrast is still more striking when the strata here dealt with are compared with the Cretaceous beds described by Prof. Zittel from the monastery of St. Paul, somewhat further to the north, his remarks being based on Dr. Schweinfurth's sections and letters. Instead of the limestone attaining a thickness of 50 metres or less, at the convent above-mentioned, beds 380 metres thick are recorded, while in the list of fossils obtained we seek in vain for those which are characteristic of the Cretaceous exposures in this area.

On the contrary, the presence of *Hemiaster cubicus*, of *Pseudodiadema variolare*, and *Heterodiadema libycum* shows that it is no longer a shallow-water and variable Senonian fauna, that is being dealt with, but a deep-sea deposit which had already commenced to be formed in Cenomanian times. In other words, the St. Paul beds, like those of Western and Eastern Sinai (studied respectively by the present writers) belong to the great series of Cretaceous limestones which should be ranged under Zittel's term "Africano-Syrian Facies." Nevertheless the variable strata described by the writers from the more southern regions, too, find their nearest representatives in the South Algerian localities, many of the principal species being identical. Dr. Blanckenhorn's paper mentioned above is the first attempt to subdivide these Cretaceous beds on palaeontological grounds, and as a result of his examination of the fossils, he refers most of the limestones in this area to the Middle Senonian or Campanian, *i.e.*, the *Villei* stage, but as has been seen, the beds in this district rarely exceed 40 metres in thickness, and have a decidedly shallow-water aspect, while at the convent of St. Antony the Cretaceous beds are enormously developed (380 metres). In his list, he further gives Danian as being present at Abu Zeran, *Libycoceras Ismaeli* having been found at that locality. As a matter of fact, these Ammonites were in a bed immediately overlying one entirely composed of *Ostrea Villei*, and in intimate connection with the large Nautili, so

that there is little doubt that this species here occurs in the Campanian series, and the existence of Danian remains problematical, or more strictly speaking, is improbable.

The conclusion then is, that the Cretaceous Limestone of the area now described is of shallower-water origin than that occurring to the north, and from the identifications at present to hand, is probably entirely of Campanian age,* *e.g.*, Middle Senonian, being characterised by the abundance of its oysters, its well-marked bone-beds, and small thickness.

This main type is further of great palæontological variability, the beds near Qena, Qosseir, and Jebel Zeit or Mellaha differing in essential particulars. In all cases where the exposures are good, unconformity is recognized between these beds and the overlying Esna shales.

The lack of uniformity in the Cretaceous beds is in sharp contrast to the identity of character noted in the Eocene strata occupying the same area.

W.F.H. & T.B.

Section VI.—GYPSUM.

This rock was first met with in the neighbourhood of Qosseir, a kilometre or two to the west of the town. It crops out from under the Beach Deposits, which here form a bold escarpment about 152 metres above sea-level, the former rising to 182 metres above the sea. The junction with the Beach Deposits was unconformable, a sharp line of demarcation being everywhere noticeable. This gypsum forms a line of round-topped, buff-coloured hills which stretch away to the north. Its surface is covered by a curious, hard, coralloid growth which is difficult to walk on, and which cuts up boots very badly. If by any chance one trips up on it, the result is disastrous in the extreme, as numerous points of this growth peel off large pieces of skin from one's hands and arms. Climbing on this rock is very dangerous, on account of its rotten and treacherous nature, and also because of the narrow, steep-sided, dry water-courses.

To the north and south of Wadi Hamrawein † an exposure of gypsum 7·5 kilometres long by 3·5 kilometres at its widest part also occurs, the peaks rising through the Beach Deposits like islands in the sea. Here, as in the previous instance, a section shows gypsum on the top of the

* Bullen Newton, after examining Barron's original collection of pelecypoda from near Qus, concluded that the beds containing them were Turonian in age, but the cephalopoda subsequently found show, in the writers' opinion conclusively, that Dr. Blanckenhorn's identification of these beds as Campanian is the right one.

† Plate III.

hill, underlaid by greenish shales, followed by another-bed of gypsum. Further investigation of this section was impossible owing to its being hidden by a deposit of gravel, but it is noteworthy that beyond this point Nubian Sandstone appears. It thus seems possible that these gypsumised limestones, belong to the Eocene and Cretaceous formations. The shales above referred to correspond to the Esna shales, while the gypsum is the pink limestone which forms the base of the Eocene limestone. Since these beds actually occur to the west of the gypsum, it is practically certain that they are identical.

Looking at the relations between the Beach Deposits and the gypsum,* one cannot help being struck with the idea, that at first the latter beds were overlaid by the former, but afterwards, owing to the spongy nature of the gypsum, it withstood denudation better than the limestone, and consequently slowly rose above it. This is further supported by the fact that the height of the gypsum hills scarcely varies 1 metre in this area, thus suggesting a "plain of marine denudation." Between Wadis Hamrawein and Abu Hamra two more exposures of this rock are seen; the first and most westerly having its longer axis north and south, measures 3 by 0·5 kilometres, while the second is a triangular patch with its apex pointing eastward, its length being 4·2 by 2·2 kilometres at its base.

Another lenticular area, having its greatest extension northwards and measuring 5·5 by 2·7 kilometres, occurs between Wadi Sodmein and Wadi Queh.

Between the two wadis bearing the name of Queh and stretching north as far as Wadi Salem, a long ridge of gypsum lies on the flanks of the diabasic rocks, a thin wedge of Nubian Sandstone being interposed between them towards the northern limit of the exposure. The total length of this deposit is 16 kilometres, and its width in its southern half is 2·7 kilometres, gradually narrowing to 1 kilometre at its northern end.

At Wadi Abu Shigeli this rock forms fringes jutting out into the Pleistocene, being backed by Nubian Sandstone, but where the igneous foot-hills run sharply back to the west towards Jebel Abu Diab, it suddenly widens out into a mass of low rounded hills which run down in a tongue into the Pleistocene, and extend to the north as far as Wadi Safaja.

The total length of this patch is 11 kilometres, with a normal width of 3·2 kilometres, except in the tongue which is 6 kilometres wide.

* See Plate III.

Here also it is backed by Nubian Sandstone and shales, the latter forming one or two isolated hills capped by some Cretaceous limestone.

To the north of Wadi Barud another exposure of gypsum appears from under the Beach Limestone. Here it does not form hills at all, but rises from under the later deposits in continuation of the slope from the sea-coast.

From this point as far as Ras Jemsa,* no other exposure of this rock was noticed. In this headland, which is a broken fold, gypsum again comes to the surface. Here occur the old sulphur mines which were worked from 1865, the whole headland being honeycombed with galleries and workings for the extraction of this mineral. Later on this headland was exploited for petroleum, but the search was eventually abandoned.

The sulphur occurs in cracks or pockets more or less sporadically distributed in the gypsum, but it is now practically worked out.

From this headland the gypsum dips away underneath the Beach Deposits, and is next met with at Jebel Zeit;† in this range it occupies a large area, in places entirely forming the hills, while at others it lies only on the sides. The dark igneous rocks and the buff-coloured gypsum make a very sharp contrast and stand out clearly from each other.

In this range ‡ further light is thrown on the age of the beds from which the gypsum has been formed. On its west side behind Jebel Zeit, a section was met with which almost certainly proves that it is the limestones at the base of the Eocene and those of the Cretaceous which go to form the gypsum in all cases. Starting from the edge of the range and going towards the centre the following beds were met with :—

1. Pink limestone converted into gypsum and still shewing its bedding. (Eocene pink limestone).
2. Greenish shales } Esna Shales.
3. Bed of gypsum } Esna Shales.
4. Greenish shales } Esna Shales.
5. Massive gypsum. Part Esna beds, part Cretaceous.
6. Sandy and marly beds } Cretaceous.
7. Red ochreous sandstone } Cretaceous.
8. Granite and quartz-felsite.

This section can be paralleled exactly in many places in the Eastern Desert, where no doubt exists as to the age of the beds, so that there can be no question as to the correctness of the determination here.

In this area much tearing and faulting of the beds has taken place.

* See Plate VI. † See Plate V. ‡ See Plate VI.

In the section just described, the dip was towards the west and away from the centre of the range. At different places where the igneous rock rises through the gypsum, the sandstone which underlies the latter in many cases does not appear, thus proving a rending or tearing of the beds. Step-faulting is also very prevalent in the range to the north of the igneous hill of Jebel Zeit proper.

Here in a main drainage wadi which cuts through the Beach Deposits and the range, step-faults are seen on either side of the centre of the hill. These are well-marked, as was previously stated in the description of the Igneous Gravels, (p. 126)by small terraces of igneous pebbles, 98, 73, and 58 metres respectively above sea-level. The faults are likewise proved by the reduplication of the beds in the wadi, and also by the formation of small waterfalls by the hard beds of anhydrite which occur in the gypsum. This wadi is different from the other drainages in the fact that its bed is cut down practically to base-level, while the majority of the others come over a cliff into the plain. The most feasible way to account for this feature is by supposing the watercourse to have formed along an east and west rift. This seems to be the only explanation possible when it is remembered that the formation of the wadi is subsequent to late Pleistocene times. The fact of the majority of the water-courses ending in a cliff also argues a sudden rise of the range, and this is borne out by the discovery of Pleistocene beds at two different levels—on the top of the range, and at the foot of it in the plain.

The gypsum in certain places, both on the east and west side of Jebel Zeit, was overlaid by a hard siliceous sandstone which was very puzzling at first, but later on was found to underlie the Pleistocene coral-reefs.

The characters of the gypsum on the surface are similar to those already described in the exposure near Qosseir. Internally it differs somewhat, here the layers shew much contortion, strings of greenish clay appearing here and there in the mass. In addition, the latter is traversed by cracks and fissures in directions more or less at right angles, which are filled by massive selenite. In a wadi to the north of the petroleum wells, massive selenite mixed with anhydrite was found, and scattered sporadically through the mass were kernels of sulphur. The anhydrite here occurs in a bed about 8 metres thick and seems very pure, and associated with it are beds of crystalline gypsum or alabaster. These crystalline beds however seem to be the direct result of the faulting, as they were not seen except where the step-faults occur. With reference to the selenite found here, it showed

a curious tendency to become opaque-white along the cleavages, probably by becoming dehydrated.

Between Jebel Zeit and Bir Abu Nakhla, gypsum again crops up from under the Beach Deposits, but as no sections were exposed, no extended observations were possible.

On the sides of Wadi Dara to the east of Dara Hill, gypsum of the same character as that previously described also occurs. This does not cover a very extended area.

Origin of the Gypsum.—It has been previously stated that in no single case have any of these deposits of gypsum been noted outside the Raised Beach area. This fact was early impressed upon the writer while mapping the plain on the eastern side of the Red Sea Hills. Although feeling morally certain that there was an intimate connection between the Beach Deposits and this rock, close search failed to establish it. It was noticed that the gypsum was the result of the metamorphosis of Cretaceous and Lower Eocene limestones, these being found unaltered outside the Raised Beach area, although at the same time, proof was wanting to show in what way the action went on. It was only while engaged in mapping these beds in Sinai, on the eastern side of the Gulf of Suez, that a clue was found. Here a large area of gypsumised rock, from which the Beach Deposits have been removed, is exposed between Wadi Feiran and Wadi Sidri. On walking over the escarpment of these beds, a sudden transition took place into ordinary limestone. This was seen at once to be due to a strike-fault which had let down higher beds against them. Following up this fault, it was found that the throw gradually became greater, thus exposing marly beds which were gypsumised at the top, but further down fossils of Cenomanian age, were found with small needles of gypsum round them. This showed that the change did not take place from below but from above.

Prior to the formation of the Geological Survey the plain to the east of the igneous range of the Red Sea Hills was examined and mapped from Abu Sha'ar to Jebel Gharib by L. H. Mitchell.*

In this report, in describing Ras Jemsa, he ascribes the alteration of limestone to gypsum to the chemical action of sulphuretted hydrogen gas rising from a supposed igneous intrusion, for the presence of which there is absolutely no evidence. It will thus be seen that as far as observation goes it is in favour of alteration from above, and not from below. Moreover, Mitchell attributes the alteration of the gypsum at

* *Ras Gemsah and Gebel Zeit: Report on their Geology and Petroleum.* Cairo, 1887.

Jebel Zeit, to the intrusion of the granite of the range into the overlying rocks. This also is impossible, as these rocks rest unconformably on the surface of the granite.

Viewed as a whole, there has been no instance met with which favours Mitchell's view of the origin of these gypsum deposits. It thus seems that the metamorphosis of limestone into gypsum in this area is due to action of the sulphuretted hydrogen generated during the decomposition of the organic remains in the overlying beds and the subsequent oxidation of the sulphide into sulphate of lime. T.B.

Section VII.—NUBIAN SANDSTONE.

The deep brown-red sandstone, so well displayed in Nubia, attains a considerable development in this area and owing to its lithological peculiarities has had a material effect on the topographical structure of the country. It has for many years been a subject of discussion amongst geologists, the chief points involved being its age and its relation to the underlying igneous rocks.

I. *Age of the Sandstone.*—As Prof. Zittel has justly remarked, the dispute as to the age of these beds is largely due to the fact that strata of different periods but similar lithological character have been confounded under the same name, and it is also probable that the sandstone is largely due to the same physical cause acting on similar rock-materials which have come under the influence of marine denudation at different times. The result has been the promulgation of three views, each supported by good authorities: 1st, the Nubian Sandstone is older than the Cretaceous; 2nd, it is mainly Cretaceous; 3rd, it is Post-Cretaceous.

1. That a part of the Nubian is undoubtedly Pre-Cretaceous was proved by the discovery of *Orthis Michelini* by Bauerman in Western Sinai, which led Tate and Davidson to support Salter's view that the beds containing them were Carboniferous. This fauna and its relations will be dealt with more fully in the Western Sinai memoir. On the Egyptian side of the Red Sea, Schweinfurth also proved the existence of these beds in Wadi 'Araba, and the succession was examined and elaborated by Walther. Thus part of these sandstones is undoubtedly Carboniferous. No definite proof of the Permian exists, but Blandford has found that the Abyssinian rocks of this nature are overlaid by Jurassic beds, so that they may possibly be Triassic or Permian.

Many other writers have classed these strata as Triassic, chiefly on account of their resemblance to the Red Triassic formation in Europe, but to these conclusions little importance can be attached. It may be at once stated here that there is no evidence in this area of sandstones older than the Cretaceous.*

2. The second, and most important group of writers, includes those who have definitely considered the Nubian as Cretaceous, though its precise age has been the cause of much difference of opinion. Thus Russegger, Ehrenberg, and Lefevre regarded it as Lower Cretaceous, while Zittel, following Schweinfurth, has mapped most of these sandstones as Cenomanian, though in his table on p. XCII (bc) he places the Nubian as Senonian.

3. Finally, Fraas has suggested that the Nubian Sandstone between Qena and Qosseir is of Tertiary age, a conclusion that the writers' results and those of his son, Prof. E. Fraas, render absolutely untenable.

If the Carboniferous age of part of the sandstone has been clearly proved, it is equally true that the uppermost part of the Nubian, both in Sinai and at the Convents of Wadi 'Araba, is overlaid without any visible break by limestones containing abundant Cenomanian fossils, so that the Cenomanian age of at least the highest members of the series may be considered as practically settled. South of latitude 28° N., however, it has been seen, when discussing the Cretaceous limestones, that no distinct Cenomanian fauna has at present been met with, but that the fauna is Middle Senonian in its aspect, so that the higher strata of the sandstone now being considered are younger than those further north and in Sinai. This view is supported by Dr. Blanckenhorn's identification of the fossils from El Geita, collected by Barron and Fraas, as *Ostrea Boucheroni* and *Ostrea Bourguignati*, which are Santonian, or Lower Senonian forms in Algeria, a conclusion which is welcome as agreeing with the views arrived at on other grounds.

II.—*Have the underlying granites been intruded into the sandstone, or does the latter unconformably overlie the igneous rocks?*

This question from the writers' point of view admits of but one answer, viz., that the Nubian has been laid down on an eroded surface of an old igneous region. Both here and in Sinai, sections are constantly met with showing dykes which have penetrated the granite or metamorphic

* This point is of direct practical importance, as one of the theoretical reasons adduced in support of the existence of petroleum in paying quantity is the supposition that this sandstone, like the oil-bearing variety in America, is Devonian in age. This view, which has already led to the expenditure of thousands of pounds, is entirely unsupported by any evidence, whether stratigraphical or palæontological, and can only be due to the wish being father to the thought.

rocks cut off sharply at the point where they meet the superincumbent sandstone, while over the whole of the Arabian Desert there is scarcely a single instance of the intrusion of igneous rocks into the sandstone itself. This does not mean to say, that there may not have been some intrusions into, or through the Nubian, for it has already been stated as one of the interesting features in Abu Had that an andesitic rock has been intruded into beds as young as the Eocene, while Beadnell has obtained similar cases near Assiut, and Dr. Schweinfurth has mentioned an interesting case in Wadi Mor, near Gharib, where coarse-grained granite with prismatic jointing has altered the sandstone.*

In Western Sinai, too, similar occurrences are well-known, and Walther† gives a picture of an eruptive dyke in Nubian Sandstone at the foot of Jebel Abu Darba, while other examples of the same nature have been met with by Barron.

Further south, at Jebel Burka, about 20 miles W.N.W. of Wadi Halfa, Captain Lyons has noted the intrusion of a mass of olivine-dolerite into the Nubian Sandstone,‡ and Hume has found a columnar sandstone at the Kaibar Cataract, near Dongola, similarly owing its origin to a dyke of porphyrite.

Still, speaking generally, after an examination of wide regions of the Arabian Desert and Sinai, the cases known are among the rarest occurrences. In general, too, the intrusions occur at some distance from the main area of igneous rocks. Special stress has been laid here on this point because at least two recent writers have maintained the intrusion of the igneous rock into the overlying sandstone as a prevalent feature.

Nubian Shales and Sandstones.—To the south-west these strata occupy the area between the Cretaceous and Eocene escarpments of Wadi Hammama and Jebel Abu Had and the igneous ranges and valleys of Jarra-Jidami and Fatiri-Abu Shia. On the eastern side of the watershed, they form a mass of low hills parallel with the main range of Jebel Duwi, there being also a large outcrop of these beds along the Safaja range to the south of Wadi Safaja. They also take part in the synclines at the confluence of Wadi Safaja and Wadi Wasif, and north-west of Wadi Um Tagher.

Wadi Hammama and Wadi Jidami.—At the confluence of Wadi Hammama and Wadi Gareya, the highest member of this series, the

* Petermann's Mittheilungen: vol. XXIII, 1877, X, p. 388.

† *Korallenriffe der Sinaihalbinsel*, p. 459,

‡ "On the Stratigraphy and Physiography of the Libyan Desert of Egypt." *Quart. Journ. Geol. Soc.*, pp. 531-547, 1894.

carbonaceous shales* (previously mentioned as underlying the Cretaceous limestones), forms the base of the cliff, passing downwards into sandy beds, which rapidly change into highly ferruginous sandstones dipping north-west at an angle of 3° or 4°. The denudation of these sandy beds has given rise to a broad plain, dotted over with small, conical, yellowish-green knobs, to the east capped by the dark-brown ferruginous sandstone.

On the side of Wadi Jidami near its junction with Wadi Markh is a ridge, composed of the ferruginous sandstone, intercalated with a lighter-bedded sand-rock. In the upper band of the ferruginous sandstone two large hollow vertebræ of Mosasaurus were found, together with fish-teeth immediately above in a lighter band, several nodules, of a radiating fibrous structure, being noted, resembling phosphorite in character and lustre.

Small beds of glauconitic sandstone are also present below the vertebræ-bed, in addition the lighter sand-rock showed worm-tracks and ripple-marks, while on the low ridges of light sandstone in Wadi Hammama well silicified specimens of wood, still exhibiting distinct traces of vascular bundles, woody tissue, etc., were obtained. Beyond this point, the beds are seen to be rolling gently, low dips of 2° east, west, north and south having been noted, but the general dip of the whole is north-west. In general, the lower beds are very friable and fissile, while the harder ferruginous beds above weather into flakes of slaggy appearance. Throughout the series, the yellow flaggy sandstones show evidence of ripple-marking, sun-cracks, rainprints, and worm-tracks.

Passing eastward, the sandstones become more massive, giving rise to a plateau, rapidly becoming higher as the igneous range is approached, and forming bold cliffs on either side of the wadis which have cut through them.

Wadi Jidami.—At a point some kilometres west of Jebel Jidami the sandstone hills widen out and igneous rocks appear in the low plateau at their foot. The junction of these two series can be well seen here, and the succession from below is as follows:—

Decomposed kaolinized granite.
Compact sand-rock, the sand grains being cemented by felspathic decomposition-products.
In certain places, layers of pebbles of quartzite, 2·6 centimetres in diameter, were scattered through the sand-rock.

The main mass of the hills was composed of flaggy sandstones and grits, dipping steadily about 3 degrees west. No evidence of any fold

* Presumably these are the beds in which it is hoped to find coal at Redesia.

was observed, from which, together with the lack of any igneous intrusion or alteration, it is to be concluded that the Nubian Sandstone was laid down on the eroded surface of the granite. This is further confirmed by finding these sandstones overlying all types of the igneous rocks at their junction, and resting on the eroded edges of grey granite in the form of isolated ridges and cones, with sharp vertical escarpments and flat tops (see Section X.).

Wadi Sellimat.—The same feature was observed on a return journey in Wadi Sellimat, where the Nubian Sandstones rest on the irregular surface of the dolerite rocks.

The actual junction with the igneous rocks can be observed at many points, and very clearly at a bend where the wadi had cut through both series. Here, as elsewhere in this district, the sandstone forms bold escarpments facing the igneous rocks which it originally overlaid, and from whose surface it has been removed by erosion.

At the line of junction occurs a bed consisting entirely of quartzite pebbles, and above this a mass of arkose is present, which in places has a thickness of 18 to 20 metres. These sandstone beds are most coarse where they join the crystalline hills on the east, and in their western extension are seen to become more clayey, the sandstone gradually thinning out and passing into the carbonaceous and greenish shales at the base of the Cretaceous plateau.

Nagateir Plain.—The high and continuous sandstone plateau after overlying the granite foot-hills of Missikat el Qukh and the low dolerite hills of Wadi Markh and Wadi Abu Shia rapidly lowers towards the north-west, breaking up into low isolated knolls on both sides of Wadi Markh, finally being represented by low ridges in the Nagateir plain, where it disappears under the gravels. The great plain itself is probably due to the denudation of the soft flaggy sandstones of the Nubian series, which crop out in it at various points. To the south-west of Jebel Abu Had the Nubian Sandstone plays a great part in the hills which bound the wadis draining into Wadi Markh. In this region faulting has been very complex, Tertiary beds having apparently been thrown down to the east of the Nubian strata. Low sandstone ridges in these valleys have dip-slopes of over 12°, and are certainly due to faults.

The Eastern Nubian Sandstone.—This rock in general character resembles that of the western side. In the neighbourhood of Jebel Duwi* it is everywhere present between the Cretaceous and Metamorphic series, conformably underlying and passing into the green shales at the foot of the Cretaceous escarpment. On the south side of the Duwi

* See Plate III.

range these sandstones markedly overlap the metamorphic rocks, *e.g.*, near the Lokala in Wadi Seyala. Here the maximum dip observed never exceeded 15° in a west of north direction. Other dips were likewise observed, one being 12° N. 15° E, and the other 14° E, 15° S; these seem to indicate a distinct roll in the beds at this point. The Nubian Sandstone contains at the base numerous quartzite pebbles, and small fragments of dark-green rock, probably chlorite-schist, and a little higher in the series consists of sand-grains, closely cemented together by calcareous material.

At the north-west end of the Duwi range the Nubian Sandstone reappears at the head of Wadi Saga, forming low ridges, low hills, and isolated outliers on the metamorphic rocks.

The Nubian Sandstone also forms a fringe on the eastern side of the igneous range to the south of Wadi Safaja. Here it has been faulted down to the east, underlying gypsum, and the overlapping beach deposits. At the junction of the Wadi Wasif and Wadi Safaja,* there is another patch of this rock forming the floor of the faulted syncline. It forms three sides of this basin, the dips in all cases (which vary from 5° to 15°) being towards its centre.

The character of the sandstones and shales does not differ from those in the other places referred to above, and they lie unconformably on the igneous rocks surrounding the basin.

In the syncline of Um Tagher, the Nubian Sandstones and Shales are practically the same as those in the syncline of Safaja, except that the dip is more constant, being 10° west. Here the beds unconformably overlie the coarse red granite which forms the flanks of Jebel Barud.

The Nubian Sandstone also occurs on the the top of a spur of Jebel Nugara, evidently the remains of these secondary rocks which have been faulted down, the dip being almost nothing.

Wadi Qena has not at present been examined north of the Qena-Um Disi track round the north of Abu Had, but judging from Zittel's map, a strip of Nubian Sandstone (*Ælterer Cenomanstein*) lies along the western borders of the Red Sea Hills between latitudes 27° and 28° N. Unfortunately, it is difficult to estimate the precise value of this conclusion, because the strip is made to thin out completely to the south just at the point where the present researches show it to be thinning northward, the result being that this map shows the Nubian Sandstone extensively developed where Zittel's has none at all. A comparison of the two will show how fundamentally the geology of the south-west corner of the present area differs from previously published results.

*See Plate IV.

On the eastern side of the Red Sea Hills the Nubian Sandstone again reappears in the north-east portion of the district, its presence giving rise to well-marked topographical features. Owing to the existence of folds striking north-west and south-east the sandstone reappears between Jebel Mongul and Jebel Zeit, in each case giving rise to broad plains or valleys. Opposite the mouth of Wadi Dib it is seen to form part of a syncline, as the sandstone passes under the Mellaha limestone chain,* on the western side giving rise to a plain which extends to the foot of the Red Sea Hills, while on the eastern side it produces the longitudinal valley which for many kilometres separates the limestone ridge from the granite ranges of Abu Dib, Abu Had, and 'Esh. Finally, in Jebel Zeit itself,† at the foot of the igneous mass which forms the centre of the chain and between it and the gypsum hills, the sandstone in characteristic form is present, first giving rise to a narrow valley, and further north rising into well-marked hills.

The more detailed notes connected with these exposures are as follows: 1. After crossing the plain from Bir Dokhan to Bir Mellaha, and passing through the Eocene and Cretaceous hills previously described, the latter are seen to overlie a ferruginous somewhat massive sandstone which, like the other sedimentary rocks, is dipping 4° west. The plain which follows has a very quartzose rock at the surface, and has pebbles of quartz scattered over it, while small hillocks composed of the same material were observed close to the junction with the granite. As Mitchell has strongly supported the view of the igneous rocks having intruded into the sandstone, the junction of the two was carefully examined. At one point a porphyritic fine-grained andesitic rock appeared to rise through the Nubian, and was of a redder colour near the junction, but the sandstone itself showed no trace of alteration, while in all other cases it lay on a flat weathered surface of the igneous rock. In many instances it was seen to overlap on to the igneous rock, and by its general dip shewed that it had at one time covered it. The greater part of the igneous rock was a lava into which dykes of a more basic character were intruded, but even at the junction with this latter rock no alteration was seen, nor did this rock enter the sandstone at any place; thus all observations are against the views above-cited. The sandstone which is present between the gypsum and granite, etc., at Jebel Zeit is of much the same nature, but at many points has a high dip when in contact with the igneous mass, probably due to faulting produced by differential movements of rocks of two different consistencies. A noticeable feature is the bright tint of the beds nearest to

* See Plate VI. † See Plate VII.

the granite, due in the writers' opinion to the intermixture of the very varied materials derived from the granite and the dykes penetrating it, which by their denudation have given rise to the sandstone, and not to a contact metamorphism produced by the intrusion of a liquid magma, the colouring not being of necessity close to the junction, but capriciously distributed. Again, as has been remarked above, the Nubian extends from the point where Wadi Dib leaves the Red Sea Hills to the northern end of the Mellaha limestone chain, having the characteristic features described in the previous pages.

Nubian Sandstone also occurs in the plain from a point 3 kilometres south of Bir Abu Nakhla to the northern edge of the area.

West of the well it is 3.5 to 4 kilometres wide and is let down by an east and west line of fault against the igneous hills, in one place shewing a dip of 5° towards the fault. That this is a very much disturbed area can be seen at a glance, Eocene and Miocene in turn being laid against the broken ends of the sandstone, and it is almost certain that a large area of this rock is masked by the covering of Pleistocene gravels lying on the plain up to the foot of the main igneous range. For the relations of the beds in the neighbourhood of Wadi Dara see Section III.

Wadi Dara.—In the plain to the north of Wadi Dara and near the faulted Eocene ridge described in the chapter on that formation, Nubian Sandstone is found underlying Miocene limestone, the latter tilted at an angle of 12° to the south-west. Further north the rocks were again seen lying on the edges of the sandstone, the former dipping 10° to the south-west, while the latter was inclined 30° to the north-east.

About 2 kilometres to the north-east is a hill the top of which is formed of Miocene limestone, its base being made up of the marls and shales of the Nubian Sandstone; the former dips 8°, the latter 30° to the north-east. In these marls occur beds containing numerous oysters of different species.

Some of the remarks made by Mitchell on the sandstone and the overlying limestones also add information as to their occurrence. Thus he says:* "In the Coast Plain, this series was found to extend along the side next to the watershed range from opposite Jebel Dara to Jebel Gharib. As has been hitherto remarked, it was the upheaval of the Upper Cretaceous beds along the line of the Jebel 'Esh range in the Great Plain, and their subsequent wearing away along the line of their tilted edges, that originated the range of hills which I have named the

* *Loc. cit.* p. 22.

Limestone Chain. Along this chain the beds of the series dip south-westerly at angles varying from 10° to 15°; while, on the side of the plain next to the Watershed Range (*e.g.*, main Red Sea Hills) they are tilted in an opposite direction, as for instance, in the neighbourhood of Jebel Mongul, where they dip at an angle of *from 75° to 80° north-easterly*" (the italics are the writers').

With regard to the thickness of the beds, it is difficult to arrive at a very exact estimate, but Mitchell has given 210 metres as their thickness at Wadi Dib, and 150 at Mellaha.

The following conclusions may now be stated:

1. The Nubian Sandstone in this area is mainly Senonian, *i.e.*, Santonian.
2. There is no proof that any part of it is Pre-Cretaceous.
3. It is younger than the great mass of the igneous rocks now composing the Red Sea Hills.
4. Its upper part consists of soft shales giving rise to plains and valleys, its lower strata being hard sandstones with quartz pebbles, in the south-west forming marked plateaux.
5. Its average thickness is probably about 200 metres.

The total thickness of the sedimentary beds in this area is thus:

Eocene, at least...	345 metres.
Cretaceous Limestone	50 „
Nubian Sandstone	200 „
A grand total of nearly	600 metres or 2000 feet.

Note.—The arguments in favour of the view that the sandstone has been intruded into by the granite on the large scale will be found in Mitchell (*loc. cit.*) and in the following works:—

Floyer, E. A., "Notes on the Geology of the Northern Etbai," *Quart. Journ. Geol. Soc.*, Vol. XLVIII, pp. 576-582, 1892.

Johnson, E.A., and Richmond, H. Droop "Notes on the Geology of the Nile Valley," *Quart. Journ. Geol. Soc.*, Vol. XLVIII, pp. 481-484, 1892.

Curiously enough, in a recent paper "Exploration Geologique dans la Peninsule Sinaitique" by M. Raboisson, read before the *Institut Egyptien,* a preliminary copy of which lies before us, the first point he struck was the locality where a porphyrite actually had entered the overlying sandstone, and consequently he at once rejected the views held by M. Lartet, which are the same as those adopted in the present memoir. On his return journey (p. 64) he finds that the veins terminate under the "grès" without penetrating it, except for certain fragments, of very varied dimensions, angular and in no way rolled, and concludes that the eruptive push appears to have spread them in the sandstone and intimately mixed them with this rock.

Section VIII.—FOLDS, FAULTS, Etc.

From what has been previously stated, it will be seen that the area under consideration has been the scene of important earth-movements, which have been the principal factors in determining the structure of the country. The faults and folds which will here be discussed, are as follows:—

1. Qena system of faults, determining the Eocene escarpment and outliers.
2. Red Sea strike-fault systems and broken synclines.
3. The ranges parallel to the Gulf of Suez.
4. Possible transverse movements.

1. *Qena system of faults.*—These have already been referred to, so that the general conclusions need only be stated in a concise form. The main points of importance are these:—From Bir Arras to the mouth of Wadi Gurdi the escarpment west of Wadi Qena is determined by a trough-fault which has been practically traced by the writers for a distance of over 40 kilometres. On the opposite side of the valley, the scarp of Wadi Abu Had is equally accompanied by faulting, while the eastern edge of the same outlier facing the Nagateir plain is, as far as seen, bounded by a fault (here single) which ran parallel to the edge of the hills as though drawn with a straight-edge. It has been further noted that the southern outlier of Serrai has a similar dislocation determining its northern edge. Not only are the main cliffs thus connected with faults, but it has been shown that the minor valley of Abu Had is itself bounded on all sides by fault-planes. It can therefore be almost stated with certainty that wherever a vertical Eocene cliff appears in the south-western part of this area its presence is due to the existence of a line of fracture. The throw of the faults can also in many cases be determined with great accuracy, most of those examined indicating a vertical movement of not less than 100 metres. An important and interesting question arises as to the period at which this faulting was produced. It has already been stated that between the main Eocene plateau and the outliers there is in many places a plateau composed of sandy limestones overlaid by conglomerates, and that it is only in the later of these beds nearest the present drainage of Wadi Qena that igneous pebbles have taken part in their formation, while in Wadi Um Sellimat none of these have been obtained. The conclusion is thus forced on the writers that the connection of Wadi Qena with the Red Sea Hills was only established after the sandy limestones had been deposited, an important change undoubtedly, but not involving the principal fracture.

From the way in which the sandy limestones fall in the interspaces between the faults, there seems every reason to believe that they owe their existence to the invasion of the sea along the depression thus produced. The discovery of foraminiferal limestones of Pliocene age by Barron suggests that the arm of the sea above-mentioned extended to Esna during Pliocene times, probably during the 3rd Mediterranean period of Suess, and the conclusion cannot be avoided that the main fault-movement in Wadi Qena is also of Pliocene age, while if the gravels are Pleistocene, as mentioned elsewhere in this memoir, tectonic changes of importance were still continuing up to the beginning of the historical period. These conclusions are in entire harmony with the results obtained from other regions, not only the Great Rift-systems, but some of the main features of the Alpine mountain-systems of Eurasia having been produced subsequent to the Miocene.

2. *Red Sea Strike-faults and broken synclines.*—In the south-eastern portion of this area faults have again been active in producing the most complex geological and topographical features, and the examination now made has enabled the writers in part to unravel the structure of the country, and to explain the curious outliers of limestone, etc., which are scattered in bewildering fashion among the igneous and metamorphic hills.

These disturbances may be thus described. They fall principally under the heading of strike-faults, the chief being that of the Eastern Coast-Plain,* whose average bearing is 30° west of magnetic north, with occasional marked deviations from this direction. In general it follows the outline of the coast pretty closely. Its hade is towards the sea; and as a result, at the points of greatest throw, near Wadi Barud, Jebel Dokhan, and northward, the Eocene and Cretaceous beds have been thrown down against the igneous rocks, and become covered up, (especially north of Wadi Barud) by unconformable Pleistocene deposits. It is probable that the preservation of these Eocene and Cretaceous rocks is entirely due to their having been faulted down.

The great Coast-Plain fault was first met with on the Qena-Qosseir road where it leaves the hills. Here the throw was not great, a node of the fault evidently occurring a little distance to the north. To the east of this a small fault hading west also occurs parallel to it. A little further to the north, and about 3 kilometres south-east of Wadi Hamrawein, it was again met with throwing down Nubian Sandstone, and further north some black diabasic rocks, against a granite ridge. About 2 kilometres to the east, and running more or less parallel to it, another fault throws down the Eocene against the diabasic rocks;

* See Plate III.

but it was not traceable for any distance, because it was covered up by the Pleistocene gravels.

The main fault continues more or less parallel to the coast line, gradually approaching the latter until at Jebel Nugara they almost meet. Up to this point Nubian Sandstone is the main rock seen lying on the flanks of the igneous range, a few patches of Cretaceous being also noted at Wadi Safaja.

It also appears probable that there have been two periods of movement along this line of fracture, the first having the above-stated results, the second, throwing down the Pleistocene, and leaving only traces of it on the flanks of the igneous range.

To the south of Wadi Barud the throw appears to have been less, as Nubian Sandstone and gypsum are found resting against the foot-hills of granite; but the movement appears to have been locally differential, the fault possessing a series of nodes. At these points the Nubian Sandstone, in places capped by Cretaceous rocks, forms most of the junction line, in all other places, gypsum or higher beds are alone visible.

A secondary fault, parallel to the main line of fracture, has been inferred in the district to the north-east of the Jebel Moghat range, there being a distinct escarpment of doubtful Tertiary rocks running parallel with, and at a distance of 5 kilometres from the main fault-line, the drainage from Wadi Abu Garia, Wadi el Shayeb, and Um Kabbash being also deviated from its straight course to the sea, and running parallel to the escarpment as long as the latter is visible, then again bending sharply seaward.

The main line of fault can be followed from this point to a little north of Wadi Mattur where, owing to the lowering of the hills and the obscuring of the evidence by gravel, etc., its presence can only be inferred. Actual proof of its existence is, however, again met with on the north side of the road leading from Bir Dokhan towards Jebel Zeit, in a small area of Eocene beds which have been let down against the igneous foot-hills, and it is undoubtedly continued against those of Jebel Kufra and Abu Marua on to Jebel Mongul and Dara where it was again met with, being continued to Jebel Gharib.

In Wadi Dara,* in an exposure of Miocene rocks, several short faults occur by which Eocene is thrown down against Nubian Sandstone in one instance, and against Miocene in another, while the latter is itself let down against the Nubian, the hade in all cases being to the hills or towards the south. There must therefore be a trough-fault in this region. Also by these fractures it is proved that the movement is Post-Miocene.

* See Section III.

Although, in all the faults hitherto described, their age has been shown, either by direct evidence or inference, to be Post-Miocene, and in some cases of Pleistocene age, still a glance at Section III will show that fractures of Pre-Miocene age also exist. From this section it will be seen that the first fracture took place before the deposition of the Miocene, and that this movement continued after these rocks were deposited. These faults were in all probability the beginning of the movement which ended in the formation of the Red Sea and Gulf of Suez in Pliocene and Pleistocene times.

*Duwi Range with associated faults.**—This range is the result of one of a series of strike-faults having a general bearing of 35° west of magnetic north, but hading towards the hills. By this fault the beds of the sedimentary series are tilted towards the north-east, the Tertiaries being brought into direct contact with the metamorphic rocks. In this area, this range and Wadi Kobayeb are bounded both on the north and south by fault-planes, but the southern fault dies out to the south-east, and further east is entirely absent. At the north-west end of the chain there is evidence of a syncline having been broken and faulted, the Tertiary, Cretaceous, and Nubian Sandstone (the two latter in low ridges with marked change of strike,) lying in succession against the Metamorphics. In addition to the main faulting, evidences of minor faults are not wanting; thus a low ridge rises abruptly near the foot of the main chain south of Kobayeb, while further to the north-west where the valley systems are much reduced, the southern portion of the hills is much higher than the northern, and rises above the latter in a steep vertical escarpment. Finally, small faults (trough-and dip-faults) are extremely abundant, and are well displayed in a deep gorge of the Wadi Saga.

Further to the north-east, the metamorphic rocks are interdigitated with valleys in which Tertiary and Nubian Sandstone beds have been observed from a distance, the relations suggesting more broken synclines.

In the eastern part of the Duwi range, faulting is very complex. The ridge, as has been previously stated, owes its origin to a strike-fault which let down the Eocene rocks against the Nubian Sandstone; but it has undergone a second fracture parallel to the first by which the scarp is reduplicated, the beds dipping at an angle of 20°. In addition to these, it is crossed by at least four dip-faults, the most westerly carrying forward the Eocene for nearly a kilometre, cutting off the Nubian in the Wadi Nakheil, and connecting with another strike-fault

* See Plate III.

which will be noticed later, on the east side of the above wadi. The next occurs about 2 kilometres further east, and is evidently older than the first strike-fault (as is the next which occurs on the Qena-Qosseir road), as it does not cross it. The fourth, like the third, has produced a distinct shift eastward of the range of about a kilometre, at the same time letting down the Eocene against the Nubian Sandstone.

In the small plateau of Eocene on the east side of the Qena-Qosseir road the strike-fault shown is evidently the main line of fracture carried forward by the last dip-fault. Besides these there are two other lines of fracture bounding this plateau, one a dip-fault letting it down against the range of black rocks between it and the coast plain, and the other a strike-fault which meets the first near Ambagé.

On the east of Wadi Nakheil another strike-fault runs along the edge of the low ridges at the foot of the sedimentary plateau, and reduplicates the Cretaceous and Nubian Sandstone.

*Faulted Syncline of Wadi Safaja and Wadi Wasif.**—In this syncline there are two systems of faults running almost at right angles to each other. One system bears 11° east of magnetic north, while the other varies between 25° and 40° south of east. Here the conglomerates and gritty sandstones which unconformably overlie the Eocene limestones are thrown down to the east against the quartz-diorites of this region, their dip being 45°.† A second fault, roughly parallel with the first, throws the Tertiary down against doubtful Nubian, the former dipping 22° west. At the southern end of the conglomerate, Eocene limestone is let down by an east and west fault against Nubian Sandstone overlaid by the conglomerates. The main east and west fault throws down the Tertiaries, Cretaceous, and Nubian Sandstone against the quartz-diorite and the conglomerates, the Tertiaries dipping 10°. A second fault parallel to the first has let down the conglomerates, etc., Tertiaries, and Cretaceous, against the Cretaceous of the first fault ridge, the dips varying from 10° to 20° to the south. This fault is cut off on its east and west sides by two small cross-cuts, the western of which nips out part of the Cretaceous, throwing the flinty series of the Eocene against it, while the eastern is really a continuation of the main east and west fault.

This is therefore an example of a syncline broken up by strike and dip-faults.

Um Tagher faulted Syncline.‡—Here the fault bears 30° east of magnetic north throwing down the Esna series, Cretaceous, and Nubian

* See Plate IV. † See Section IX. ‡ See Plate IV.

Sandstone against the granite, the former having a dip of 20°. A subsidiary fault occurs in the Cretaceous, by which these beds are reduplicated.

3. *The parallel Plains and Ranges between the Red Sea Hills and the Red Sea.**—While in the south-eastern portion of this region the hill-systems show no very definite symmetry, between latitude 27° 30′ N. and latitude 28° N. the parallelism of the main physical features is very striking, three lower ranges running parallel to the Red Sea Hills and and the Gulf of Suez respectively, and being separated from the former and from each other by wide plains or longitudinal valleys.

Great Plain.

Thus, immediately bordering the Red Sea Hills is a broad plain, the Great Plain of Mitchell, gravelly to the south, but more sandy in its northern portion, which is cut up into low ridges by the drainage-lines rising in the Red Sea Hills, and crossing it almost at right angles. This plain extends from near latitude 27° N. to close on latitude 28° N. having a length of about 40 kilometres, and a maximum breadth east of Ras Abu Hurghada of 20 kilometres, though narrowing to the north, and having an average width of 10 to 15 kilometres. Near Jebel Mongul it is replaced, or cut off, by low foot-hills of granite in the neighbourhood of Bir Abu Nakhla.

The chief cause of the somewhat sudden narrowing of the Great Plain is the presence of the longitudinal and duplicate Mellaha-'Esh range between latitude 28° 30′ and 28° 50′ N. which owes its origin to the existence of a fault accompanied by earth-movements bringing up the different strata to the surface. The fault is the cause of the parallelism of the hills to the general trend of the Gulf of Suez, while the geological structure determined the existence of two ridges distinct in character, and separated throughout their length by a valley normally one to two kilometres broad. The western member is the Mellaha limestone range, which runs north-west for about 20 kilometres, seldom more than 100 metres above valley-level, and forming a white band only broken through by transverse gaps, where the great valleys draining from the Red Sea Hills cut across it at right angles.

Mellaha limestone range.

At its southern end between Wadi Mellaha and the plateau of Abu Sha'ar, although the evidence is not so clear as could be wished, a fault has been inferred and is shown on the western side of the range facing the Red Sea Hills. This fault evidently dies out to the north, and the beds are found lying in a syncline broken by the principal line of fracture running parallel to the main hill mass.

Where the range abuts on Abu Sha'ar, it ends abruptly in steeply

* See Plate V and VII.

tilted strata, this being due to a dip-fault which crosses the 'Esh range as well, lowering the andesitic rock sufficiently to allow of its being covered up by the limestone of the above-mentioned plateau.

Jebel 'Esh and Abu Sha'ar fault.

The fault* which bounds the 'Esh-Abu Had range was first met with on the south side of the limestone plateau of Abu Sha'ar. It was traced round the headland (Ras Abu Sha'ar) and along the eastern edge, masses of steeply tilted rock marking its course. It is probably up this fault-plane that the water of Bir Abu Sha'ar rises. After leaving the limestone and passing along the side of the igneous range, steeply tilted masses of coral limestone attested the continued existence of this fracture, which was again found at the northern extremity of the range, and was traced past Bir Abu Nakhla where it was lost under the down-wash of the plain, but everything pointed to the conclusion that it joined the main line of fault somewhere in the neighbourhood of Jebel Mongul.

An examination of the Admiralty's chart of the Red Sea and Gulf of Suez reveals the existence of another parallel fault which, from Qosseir to the Island of Safaja, hugs the present coast-line very closely. From about this point, however, it gradually leaves the coast, going outside the Jifatin-Shadwan group of islands towards the straits of Jubal, across which it passes and then bends south-east along the Sinai coast to join that of the Gulf of Aqaba. That this is part of the main line of rift running from Lebanon seems probable, as a glance at the difference of the soundings on either side of this line shows a sudden drop, at Jifatin for instance, of 280 fathoms or 504 metres. From this point, the line of fracture zigzags in and out among the small islands and reefs, the amount of drop being on an average about 100 fathoms or 180 metres until it reaches Shadwan where it rises rapidly to 200 fathoms or 360 metres close to the land; at one spot on the east side there was as much as 390 fathoms recorded. This seems to have been a point of greatest throw, as it diminishes northwards to 100 fathoms; but again on the Sinai coast it has increased to over 400.

It is thus seen that the large group of islands consisting of Jifatin, Shadwan, Towila, Gaysum, Jubal and Ashrafi, must be regarded as part of the mainland, which in time, if the same conditions prevail, will eventually be connected with it by dry land. That the coast of the Red Sea and Gulf of Suez is a rising one, is proved by the number of parallel terraces that are met with along the coast, and it is undoubtedly a favourable spot to carry out observations as to the rate of rise of the land.

* See Plate VI and V.

Returning to the consideration of the soundings on the chart of the Gulf of Suez, it is seen that the Strait of Jubal has evidently been formed along a line of fault, which is probably posterior in date to the main Red Sea fault, as the Gulf is evidently formed by a trough let down by a line of fracture running parallel to the two coasts. The western line passes just outside the islands of Jubal and Ashrafi, and bending westward runs up parallel to the shore of Jebel Zeit, at the north end of which it meets the fault seen at its foot on the mainland. This line of fracture with the corresponding eastern one can be seen on the chart to run up along the shores until they apparently unite in the line of fault which bounds Jebel Ataqa on its eastern flank.

An examination of the fault-systems on the east side of this area shows a close relation to exist between them and the Red Sea depression, the general direction of the faults and the coast-line being in close agreement, viz., about 30° west of magnetic north.

It is to be noted that the main line of folding is almost north-west-south-east, a subsidiary system having given rise to the basin-like synclines which are numerous on the eastern side of the hills, and have been subsequently broken and crushed by a north-east-south-west movement.

From the direct evidence therefore it is seen that there have been two movements along the main fault-line, the first subsequent to the Eocene, but prior to the Miocene overlying it, while the second has even involved the Pleistocene conglomerates themselves.

Whereas in the region south of latitude 27° N. the conditions suggest extreme complexity, north of that line they are on the surface far more simple. (See Section XI.) It will be at once seen that between the main range at Wadi Dib and the sea at Jebel Zeit are traces of two synclines and three anticlines, the former being connected with the plains, while the latter are represented by the two parallel igneous ranges. In each case, too, it will be noted that there is evidence of fracture and displacement on the eastern side of the anticline, a feature which is still better marked north and south of the line shown above. Thus on leaving Wadi Dib and advancing northward towards Dara, the sedimentary beds become more and more tilted, until at length the grand vertical wall of Gharib itself is probably due to a fault of over 1000 metres magnitude. Still more striking is it to find that on the eastern side of the 'Esh-Abu Had ranges, a coral-reef (apparently of Miocene age) is resting at an angle of 50°, while a Pleistocene limestone is found on the eastern slope of Zeit with a dip of 40°. Thus the topographical features of this district are produced by the presence of three anticlines

between which exist two synclines. The edge of the Red Sea Hills south of Wadi Dib has not been studied, but sedimentary rocks could be seen on their eastern flank in the neighbourhood of Jebel Mellaha.

In discussing the question as to when the main dislocations, which produced the Red Sea and the Gulf of Suez, took place, attention may be here called to an excellent compilation of present knowledge brought together by Dr. Blanckenhorn,* to which reference will be made in the following remarks. From all the evidence at present to hand it appears fairly certain that none of the greater rift-movements occurred before Miocene times. The presence of beds of the latter age south of Suez has, it is true, been noted on both sides of the Gulf of Suez,† Rothpletz having found Miocene fossils where the track between El Tor and Suez crosses Wadi Ethal, in beds 6 kilometres inland, and 150 metres above sea-level, lying trough-like and unconformably on the Eocene and Cretaceous of the coast ridges, while Gregory has identified sea-urchins from the collection obtained near Jebel Dara as having a decidedly Miocene aspect, and Newton notes oysters of the same age near Jebel Zeit. The main fact, however, is this, that none of these beds contain any trace of the Erythraean fauna, the fossils obtained being all Mediterranean. When then did the Red Sea, as we know it now, take on its present form? Blanckenhorn, following Neumayr, answers in the Middle Pliocene, or during the third Mediterranean stage of Suess. The chief reason for this conclusion was the association of a few Red Sea shells with Mediterranean ones in the Clypeaster sands of the Giza Pyramids, which Neumayr recognizes as Middle Pliocene.‡ At present the same conclusion is adopted for the rift of the Red Sea as Neumayr did for that of the North Ægean Sea, viz., that it was produced towards the end of the Upper Pliocene and as the coral-reefs are involved in the movement producing Jebel 'Esh and its neighbouring parallel ranges, these must be regarded as Miocene. Although absolute evidence is wanting, it seems most probable that the main range of the Red Sea Hills is therefore itself a product of Pliocene time.

4. While the longitudinal movements can be easily recognized and their age approximately determined, transverse folding and faulting suggests itself by inference, though the direct evidence is less than in the preceding cases. One of the most notable examples in this area is

* *Strukturlinien Syriens und des Rothen Meeres, Von Richthofen Festschrift, 1893.*

† (*Neues Jahrb. f. Min. 1893, 1. S. 103*).

‡ Blanckenhorn in his latest paper on the Miocene (loc. cit.). concludes now that the Clypeaster sands contain a purely Mediterranean fauna.

the northern front of the Central Range, which towers above Wadi Belih, running in a line almost at right angles to the directions of the folds and fault-lines previously described, until it is cut off abruptly by the longitudinal valleys of El Atrash on the one hand, and Minfeih on the other. One of the reasons which lead the writers to suspect that this range is bounded (at least to north and west) by lines of fracture, is the fact that round its edges, basic rocks (dolerites, etc.) form a fringe against the granite, while in the interior of the chain the same rocks are found capping the latter, 1000 metres above those occurring at the mountain-foot.

It also seems difficult to imagine that erosion alone would have produced such valleys as those of Belih, 'Esh, Mellaha and Abu Had in the north-east corner of the district, the two last of which have breached both the Eocene limestones, the granite and the tilted coral-reef, while the former have passed through andesite and hard coral limestone. If their ravines had been simply due to erosion, it would scarcely have been expected that the three different types of hard rock would have been breached in such a clean-cut manner, while the softer Nubian wearing away more rapidly than the other strata, should have certainly caused a deflection of the water either north or south in the plain.

Similarly, Wadi Gareya, near Qena, probably owes its origin to a transverse fissure, parallel with the proved transverse fault of Serrai, and the probable one which has determined the peculiar drainage conditions of the plain of Nagateir (see Topography, p. 12). Another example is the gorge of Wadi Barud where it passes through the high range of Nugara. It is necessary to keep the possibility of transverse fissures well in mind, as without them it is difficult to explain many features which if regarded only as products of erosion, would constitute a geological puzzle. It may be pointed out further that immediately outside this area, the Red Sea has examples of transverse breaks which in some cases exceed 600 metres vertical throw.

The tectonic changes have not escaped Prof. E. Fraas,* thus he calls attention to the remarkable east and west bend of the Nile to the west of Qena, and evidently suggests its correlation with the remarkable bend determining the northern walls of Kharga and Dakhla oases respectively. However that may be, in the present memoir we have shown that these east and west disturbances extend a considerable distance into the desert east of Qena.

* *Loc. cit.*

Amongst other points noted by Prof. Fraas, are: (1) The fault producing the escarpment on the western side of the Nile Valley; (2) A sharp fault between the Nubian Sandstone and older rocks near Jebel Hammamat; (3) The working out of the great fault-lines in the igneous ranges, these being shown in an excellent coloured plate; and (4) The great strike-fault in the Duwi (named by him the Beda) Hills, which is also well illustrated. He also remarks the curious rectangular bending of the hill ranges from a north-south to an east-west direction which, as he suggests, is to be correlated with a most important tectonic movement. These conclusions arrived at independently by so good an authority agree closely with those stated in the previous pages, the results checking each other in a satisfactory manner.

Summary.

1. The Northern Red Sea Hills are the central portion of a major anticlinal fold, partly a dome, the sedimentary beds following in regular succession on the western side of the igneous axis, and bending round in the Galala Hills from the north-south to east-west until they are cut off by the Gulf of Suez.

2. There has been differential movement in the western sedimentary rocks, faulting being most prominent where the hard Eocene limestones overlie the soft Esna shales, with the result that prominent escarpments have been produced along the line of junction of these beds all round the semi-dome.

The central Red Sea Hills and the main range of Sinai correspond, being the upthrow sides of two great faults, between them lying a disturbed area of secondary folds and faults, the beds being thrown into a series of incomplete anticlines and synclines; the principal of these are:—

a. The Great Plain syncline, with the Mellaha limestone hills forming the central axis.

b. The 'Esh Anticline (incomplete), being cut off by the 'Esh Fault on its eastern flank, with the result that highly-tilted coral reef lines the igneous hills on that side.

c. The Zeit Syncline, cut off to the west by the 'Esh Fault, and

d. The Zeit Anticline, cut off by an eastern fault bordering the Gulf of Suez.

e. The Gulf of Suez trough, bounded by faults on both sides.

f. The 'Araba Syncline, bounded on the west by the Gulf of Suez fault, and on the east either by the Qa' plain fault, or bythe principal

west-Sinai fault, following the edge of the hills and forming the boundary between the sedimentary and igneous rocks.

3. Transverse movements on a great scale have probably still further complicated the simple folding, producing in some cases mountain walls a 1000 metres high.

4. South of lat. 27° N. the movements cannot at present be classified, the most notable being the great strike-faults bounding the western side of the Red Sea.

Transverse movements are again of great importance, as in the deep rift of Wadi Barud, or determining the outliers near Qena, etc. (T.B. and W.F.H.)

Section IX.—IGNEOUS AND METAMORPHIC ROCKS.

General Features.—These rocks form a wide band, running parallel to the Gulf of Suez and Red Sea, and practically constituting the mass of the Red Sea Hills. The latitude of 27° N. again closely agrees with an important geological line, the granites playing a most important part among the components of the mountain ranges north of this line, while south of it the metamorphic rocks become increasingly prevalent as the Qena-Qosseir road is approached, the granite forming sharp isolated ridges rising abruptly from among comparatively low hills of sheared diabase or slates. Almost on the southern edge of the area, well-marked gneisses and schists give rise to the range of Meeteq, whose rugged peaks dominate the upper portion of Wadi Sodmein.

In the east central portion of the district, the lower ranges are composed of quartz-diorite which also forms the floor of many of the valleys on the northern side; through it has risen a series of parallel dykes of quartz-felsite and dolerite, giving rise to one of the most characteristic features in this part of the country. The south-eastern portion of the area is, on the contrary, composed of an intricate maze of dark hills of crushed diabase, dolerite and altered ash, the central core of which is composed of the gneisses mentioned above.

I.—Metamorphic rocks.—To the west of the Meeteq range the rocks may be classified under the following heads:— **Meeteq range.**

1. Grey shining slates.
2. Massive phyllites and slates traversed by igneous dykes.
3. Mica-schists and gneisses.

These slates were first met with in Wadi Atolla, a little south of Wadi 'Esh. At this point the wadi is bounded on the west by steep **Grey shining slates.**

cliffs of compact dolerite, and on the east by a grey, slightly schistose rock breaking off into long splinters. Through the latter run numerous solution-veins of quartz, bands of calcite and carbonate of iron, all of which have been extensively worked, though at present the object of the search cannot be stated until the chemical analyses have been completed. Between these mines and El Rebshi, the whole country is formed of low ridges of these grey and purple slates, dipping steeply south-west near the latter hill, and traversed by a reef of quartz which, running as a high ridge, forms a prominent feature in the landscape.

The quartz crystals are cemented together by a dark substance, and minute cubic crystals of iron pyrites are also present in the rock. The low hills skirting the El Rebshi and Meeteq ranges consist entirely of these shiny slates; but at the base of the former mountain-system they are replaced by the underlying green phyllites of division No. 2, into which numerous dykes of dolerite have been intruded, quartz-veins being also common. A ridge leading to the summit of El Rebshi consisted of a highly magnetic gabbro and diallage-rock, while the summit itself is crossed by a dyke of a fine-grained diorite. The country has been divided into three divisions according to the predominance of the shiny slates, the El Rebshi type of rock, and true mica-schists each of which give rise to well-marked topographical features, but as the rocks pass into one another, these lines represent spheres of influence rather than geological boundaries. The beds in the El Rebshi range and its eastern foot-hills are all dipping steeply eastward.

Green Phyllites.

Schists and Gneisses.

Meeteq.—In ascending the mountain, quartz-mica rocks of a schistose character were present at its foot, dipping 13° W.N.W. to N.W., the dip in a small chasm in the mountain rising to 45° towards the west. Here the beds, which are of a yellow-grey colour, are very strongly jointed, splitting readily into blocks more or less cubical in outline. Further up the gorge small veins of granite (one over 30 centimetres thick) run for a time parallel to, and then penetrate into the schists, in some places being pinched into these in a lenticular manner. Strong crumpling was also noted at one or two points, and higher up the valley the schists tended to become more compact. The western side of the mountain is mainly composed of these close-grained grey schists at the base, but 300 metres higher up these become more micaceous (garnets being also present in places), and are penetrated by numerous quartz and granitic veins; the summit of the mountain, nearly 1100 metres above sea-level, is composed of these mica-schists, but as in the small valleys at its foot, small pebbles of red and grey

gneiss were numerous, these rocks must compose the central core of Meeteq. From its base onward, the rocks bounding the wadi were grey schists, slightly micaceous above, and below becoming more compact, also having a steep dip eastward. Where the wadi takes a northward bend, a black, magnetic, basic rock appears in low hills on the eastern side overlaid by a crumpled serpentine, the whole being covered by much altered rock. On its western side the hills are higher, consisting of grey and yellow schists capped by dolerite.

The high range which runs east of Wadi Sodmein, and is finally cut through by it, consists of a massive red gneiss, which would form an excellent stone for ornamental work (pillars, etc.), and a more closely-banded grey variety, which also appears capable of taking a good polish. Just before the entry of the gorge, the low hills on the western side of the wadi show the following succession from above:—

Top.

1. Dolerite, compact and close-grained.
2. Purple slates.
3. Yellow, jointed quartz-schists, compact below.

One of the best sections is displayed on the northern side of the gorge, where the succession, beginning from above, is as follows:— **Metamorphic succession.**

Top.

1. Reddish-white mottled slates.
2. Hornblende-schists, with lenticular quartz-veins.
3. Massive dark dolerite.
4. Yellow, jointed mica-quartz schists.
5. Grauwacké. (?) Altered ash.
6. Mica-schists, highly folded and contorted, and of great thickness.
7. Schistose rock derived from No. 3.
8. A gabbro of purple tint, dipping 25° north-west.
9. A compact red rock, probably a granulite.
10. Closely-banded grey gneiss.

The northern end of the higher hill-system is formed by a fine range of red hills, in which quartz, hornblende and mica-schists of a typical character rest on closely-banded gneisses, but Wadi Sodmein itself wanders through a maze of hills of grey and green colour, consisting of micaceous, chloritic, and hornblendic schists capped by beds of dolerite and diabase, crushed or uncrushed.

Wadi Abu Zeran.—On the southern and eastern side of the Meeteq range, the following were the rocks observed in Wadi Abu Zeran and Wadi Um 'Arat, in ascending order:—

1. Pink gneiss, the basal rock of the series.
2. Hornblende-gneiss, associated with Biotite-gneiss.
3. Hornblende, chlorite and mica-schists.
4. Sheared diabase and other igneous rocks.

1. Considering these in detail, the pink gneiss forms a well-marked range, running more or less parallel with Abu Zeran and Wadi Um

'Arat, on the northern side, while it appears again in a high ridge some distance to the south. The range on the north disappears behind the hills formed of hornblende-gneiss and hornblende-schists before Bir Seyala is reached, the dip of the shear-plane being 80° towards the south. The character of the pink gneiss is that of a binary, rather than a ternary gneiss, mica being very sparsely distributed in it.

2. Associated with the previous rock is the hornblende-gneiss, which seems to be a connecting link between the former already described from the northern side, and the hornblende-and chlorite-schists on the south. It is practically impossible to draw a line of demarcation between the hornblende-gneiss and the schists, as the latter pass into the former by a gradual increase in the quantity of felspar. Roughly speaking, this rock stretches from the south-western boundary of this area along the north side of Wadi Abu Zeran and Wadi Um 'Arat to Bir Seyala, forming the cliffs bounding Wadi Seyala up to that place, where it is replaced by sheared diabase and chlorite-schists.

In this district the direction of the shear-plane swings rapidly round from south to north-east, and finally north.

3. In the Wadi Abu Zeran the hornblende-and chlorite-schists form a band between the pink gneiss on the north and the grey granite which occupies the plain between the north and south ridges of gneiss previously mentioned, opening out into low hills as the granite disappears on either side of the Wadi Um 'Arat. In this plain the low hills are formed of a complex of sheared dolerite, hornblende-schists, hornblende-rock, and unaltered gabbro with intrusive mica-diorite, these being replaced towards the north-east by sheared quartz-felsites, chlorite-schists, and hornblende-schists, which persist on the south side of Wadi Seyala beyond the limits of the area described.

4. *Sheared Diabase.*—This rock forms the foot-hills of the gneissose ranges, on the north side of Wadis Um 'Arat and Seyala,† alternating in places with chlorite-and hornblende-schists. They extend northward to the foot of the Duwi range, where they are unconformably overlaid by the Nubian Sandstone.

The range of Meeteq is thus of great interest as being the only true gneissose range in this district, while in addition its sections give a clue to the true succession of the metamorphic rocks. Another point on which stress must be laid is the fact that granite veins are intruded into the schistose series.

* The difficulty in the use of the word "schists" is here considerable, as the rocks in the main range are typical schists derived from regional metamorphism, while those in the foot-hills are far less compact, though not close-grained enough to be termed slates.

† See Plate III.

Wadi Saga, etc.*—To the north-west of Jebel Hamrawein, the country is again an intricate maze of low, dark hills consisting of much-sheared diabasic rocks, near Wadi Sodmein replaced by a grey andesite with porphyritic white felspars. At the head of Wadi Saga, the rocks on the south consisted of a fine-grained slate, interstratified with massive beds of compact diabase and sheared varieties of the same. In the northern ridge running parallel to Wadi Saga, diabase is also present, but closely connected with it are acid tuffs, some of which have been altered to deep red jasper, chalcedony, etc.; the former would be a good ornamental stone if there were more of it. Quartz veins were abundant, one of them carrying small quantities of haematite. Further examination of these foot-hills towards the Agharrib range showed them to be composed of red-coloured rhyolite tuffs, and crushed, banded rhyolites, associated with a compact whetstone which forms the main rock in this district.

Wadis Saga, Semna, etc.

Jasper.

Acid tuffs and rhyolites.

Along Wadi Waera and Wadi Semna, the whole country is formed of dolerites and crushed diabases, in which a diorite is probably intrusive. The latter rock has been extensively quarried in a side valley branching out from Wadi Semna, the entrance to which is marked by a large stone building or "lokala." An inscription discovered by Green at these quarries shows that they have been worked by the Romans, the diorite also being identical with the better known rock of Mons Claudianus. The quarry is still in good condition and large blocks of prepared stone are ready to hand.

Diorite of Wadi Semna worked by the Romans.

In another side valley of Wadi Semna, some small mines have been opened in the diabasic hills, the ores quarried having been limonite and yellow ochre, large veins of carbonate of iron also being present. Leaving Wadi Semna, the Wadi Um Marwat is entered, which for a time twists and turns in an intricate fashion between dark green hills of massive dolerite. As the valley opens out, these hills are seen to be penetrated by broad yellow dykes (sometimes forming broad ridges) of carbonates of iron and lime. The guide also reported the presence of mines in the persumably doleritic range of Abu Garahish some distance to the west. Opposite Jebel Abu Marwat well-marked bands of purple slates, whetstones, altered ash, and green, crushed, diabasic rocks run in alternate series along a side valley which owes its origin in some measure to the denudation of the slates. These have roughly a north-east and south-west strike, being bent into a series of anticlinal and synclinal folds with dips varying from 15° to 90°. Near the mines was an altered ash the constituents of which were cemented by iron ochre.

* See Plate III.

Iron ores of Um Marwat.

Examination of the Um Marwat range to the east of Wadi Um Marwat showed that in the low foot-hills veins of a very pure limonite were present, together with more ochreous varieties. Some of these have apparently never been worked, while others have been exhausted at the surface. In one instance the iron ores are associated with a dyke of quartz-felsite, but in most cases are clearly portions of the dolerite.

In front of the main range of Um Marwat is a prominent high conical spur, having near its summit a series of hard beds which have been bent into sharp V-shaped curves. In places the strain has been so great that the curves have been broken up into separate masses, though their position shows that they originally belonged to one stratum. On entering the valley at the base of the hill, large fragments of banded siliceous limonite were found in quantity, these increasing as the dry torrent-bed was ascended until the whole of the narrow gorge was filled with rectangular blocks, some of them measuring $0{\cdot}6 \times 0{\cdot}3 \times 0{\cdot}3$ of a metre. These were traced to the parent source which proved to be a dolerite whose edges have become extremely rich in iron oxide (some of it hæmatite), the specimens higher up being richer than those below, judging from the fragments lying on the higher slopes. The V-shaped curves are in fact, these hæmatite and limonite-bearing dykes which have undergone distortion.

The hills on the west are also doleritic and in many cases highly magnetic, fragments of the rock having a very marked effect on the compass-needle. From one of these hills the granite was seen rising to the south, in bosses and ranges through the doleritic series, so that the central granitic axis does not as such exist in this portion of the Red Sea Hills. To the north, two conspicuous, yellow hills mark a change in the geology, the granite predominating to the north, and the dolerite to the south of these, which are themselves composed of a very friable mica-granite. From this point, though topographically the dolerite still holds sway at the surface, the granite or quartz-diorite is seen to underlie them, and finally after a low ridge a little south of Wadi Safaja is crossed, forms the surface-rock.

Junction of dolerite and granite.

Wadi Safaja.

Agglomerates, Ash, etc.—This rock appears in Wadi Safaja, immediately beyond the point where the Wadi Wasif enters it. It is a greyish-green rock with numerous fine points of quartz showing in a freshly fractured surface. This rock has evidently undergone a stress, as it first shows signs of shearing, finally giving way, and becoming schistose, the plane of schistosity being north and south. This schistose rock is of no great width, and consists of soft, satiny, micaceous

layers, which gradually shade into the unsheared agglomerate. Into these has been intruded a thin sheet of black compact dolerite, breaking with a conchoidal fracture, associated with it being another dolerite, much coarser in texture and apparently older.

Further up Wadi Safaja, there is another small boss of dolerite of medium texture, which has been intruded into the agglomerate. The boundary of the latter to the south is uncertain; as far as could be seen from the tops of the hills, the country was composed of this rock.

To the north and west it joins on to the quartz-diorite or mica-granite, which forms the low hills on either side of Wadi Um Tagher. On leaving the main valley of Safaja, a mass of mica-diorite was found intruded into the agglomerate, being itself cut by dykes of fairly coarse dolerite. From this point to the head of Wadi Semna, the metamorphic rock gradually changes in character, quartz becomes less abundant, and thin veins of epidote make their appearance, the final stage of change being the whetstone rock which forms the low country as far as the Wadi Markh and the Missikat el Qukh range. The whole of the ash is honey-combed with veins and sheets of a biotite-granite, which towards the head of Wadi Semna, takes on the characters of a quartz-diorite. So abundant are these veins, that it would seem as though there were a large mass of granite underlying the metamorphic rock, which has given rise to them. **Mica-diorite intruded into agglomerate.**

On the southern side of Jebel Abu Hamra, the low foot-hills are composed of rocks of basic character in part schistose and banded, the bands being alternately dark-green and yellow. The lower portion of Abu Hamra consists of long ridges with sloping sides, these being determined by the intrusion of micro-granitic or felsitic veins (which appear of a red colour at the surface) into this metamorphic series. The upper and more precipitous part of the mountain consists of highly quartzose red granite. The schists which form a narrow band running eastward towards Jebel Um 'Anab are bounded on the south by an east and west wadi, the other side of which is formed of diorites and syenites. **Jebel Abu Hamra.**

Near the point where Wadi Fatiri enters the Nagateir plain, there is a small patch of shiny schistose rocks occurring in the black whetstone rock which forms the country at this point. Later dolerites have been intruded into these.

West of Jebel Jidami two exposures of metamorphic rock have been observed; the first one occurs in Wadi Jidami at the point where it opens out into a plain of granite close to the boundary of the Nubian Sandstone, consisting of green, slaty rocks like the German grünschiefer, **Jebel Jidami.**

standing almost vertically in low rolling hillocks, the second at the eastern entrance to the long narrow Wadi Sellimat, composed of a sheared serpentinous rock, passing into chlorite-schists, which dips steeply, sometimes almost vertically to the south-west, followed westward by a compact rock with massive bedding probably an ash, dipping in the same direction. Dolerites penetrate these in all directions, and about the centre of the pass is a felsitic rock forming beautiful columns which the writers are inclined to regard as an intruded sheet running along a north-east-south-west crack. A little further west, granite is present, pierced by veins of dolerite, while near the mouth of the valley the foot-hills are composed entirely of dark dolerite rock (containing veins of epidote) on which the Nubian Sandstone rests unconformably, giving rise to steep hills of striking appearance.

Wadi Markh.—At the head of this wadi there occurs a complex of altered hornblende-granite with dykes and veins of granite, micro-granite, and dolerite, as well as more massive intrusions of quartz-biotite-diorite. Mixed with the latter were patches of a doubtful rock, weathering pink on the surface like a limestone, but being much harder and wholly siliceous. This is evidently a sedimentary rock which has been altered by contact-metamorphism, as well defined junction-lines were observed exhibiting fluidal structure on either side.

Hadrabia Hills. A similar group of rocks was observed in the hills between the Hadrabia Hills and the Nagateir plain, the pink-white siliceous beds having a baked and metamorphosed appearance, and in places a flaky structure, forming the sides of the valley for some distance. They have apparently been affected by masses of syenite which are intrusive in this locality.

Fatiri el Iswid. Further to the north the metamorphic rocks occupy a small part of the range of Fatiri el Iswid. On entering Wadi Um Disi from the west, the road first runs through hills of granite, but soon enters into country where darker ridges predominate. Near the junction these are composed of a fine-grained ash, occurring in layers weathering in a splintery manner, this being closely associated with dolerites and crushed diabases, veined by syenite-felsites, hornblendites, and dark basaltic-looking rocks.

Near the Um Disi "deir" the high hills on the south had at their base crumpled serpentines of a green, smooth, lustrous aspect. Associated with the above-mentioned rocks were grey quartzose rocks and whetstones, while higher up dolerites occurred in thick sheets with massive jointing; the summits seem in part due to quartz-felsites rising through the metamorphic rocks, which, with the dolerites form the main mass of Fatiri.

II. *Igneous rocks.*—These may be broadly divided into: (1) the Basic, and (2) the Acid series, the former, mainly compact dolerites, predominating in the southern half of the district, while the latter occupy the greater part of the northern area. It will be convenient to deal with these in relation to the watershed, commencing with the western side first, and following the rocks from south to north.

In ascending Wadi Hammama eastward, at the point of junction between the sedimentary and igneous rocks, the Nubian Sandstone hills open out right and left, dolerite occurring at their base and forming the floor of the valley. From this point to the metamorphic region of El Rebshi and J. Meeteq, the country is occupied by igneous rocks falling into the following groups:

1. Dolerite.
2. Granites.

Dolerites of Abu Jerida.

1. Dolerite.—Occurring as a dark-green, compact, and fine-grained rock of considerable hardness, it gives rise to a confused mass of sharply ridged low hills, and to the north of Wadi Abu Jerida, is traversed by a large number of dykes of quartz-felsite which form a striking feature of the country. These dykes extend in dark-red bands running in a north-east south-west direction for many kilometres, though appearing to converge towards Jebel Jidami. Except at the western end of the valley, these dykes are mainly confined to the northern side of the wadi. Hæmatite has been worked on a large scale in Wadi Abu Jerida, being exclusively present in the dolerite and quartz veins running through it. It appears probable that the hæmatite at the western end is due to segregation of the iron ore in the dolerite itself, while further east, it seems to be present in the quartz veins only. The practical questions connected with this ore will be considered later.

Granites.

2. *Granites.*—Further east, granite appears, the change in the rock being accompanied by a change in the surface features; the hills rise steeply from the plain in rounded, dome-shaped masses, consisting mainly of a non-micaceous and highly quartzose red variety, the quartz and orthoclase being in about equal quantity. Another type is present in this district, viz., quartz-diorite or mica-granite which is easily decomposed and gives rise to wide valleys.

Wadi 'Esh.

Wadi 'Esh seems to owe its origin to the quicker decomposition and denudation of the grey granite compared with that of the dolerite which forms its northern and southern flanks. The sides of the wadi are formed of grey granite which is overlaid by the dolerite, but the former has sent veins into the latter, so that the granite must be the younger of the two. On the western side of the valley the quartz-

Granite intruded into dolerite.

diorite is traversed by veins of red micro-granite, and dolerite, in the eastern half by a dark diorite, dolerite and quartz-veins. To the south of Wadi 'Esh the compact dolerite occupies the whole country, forming vertical cliffs on both sides of Wadi Atolla, and being bounded to the east by the shiny slates of the metamorphic series. It is itself traversed by broad dykes of a later compact dolerite.

It is possible to submit the following points from a study of this district:—

1. The main mass of the dolerite is older than the granites, quartz-diorites, and quartz-felsites.
2. A more basic series, diorites and dolerites, is younger than the quartz-diorites.
3. In Wadi Atolla dolerite penetrates dolerite.
4. The quartz-veins are found in both granite and dolerite.

Judging from other districts, the red granite and quartz-felsites are certainly younger than the quartz-diorites, and also the quartz-felsites are younger than the red granite. It may be also noted that the sheets of dolerite overlaid the purple slates of the Meeteq range. So that:—

5. The dolerites are younger than the metamorphics.

To the north, the igneous and metamorphic rocks were first noted, 10 kilometres west of Jebel Jidami, forming an uneven floor on which the Nubian Sandstone was laid down. The relative age is as follows, commencing with the newest:—

Dark dolerite rocks, in dykes, veins, and sheets.

Quartz-felsites in dykes.

Red granite.

A dark hornblende-biotite-granite, whose age with reference to the metamorphic series and dolerites previously described, has not been determined.

The hornblende-granite occurs in the area between the Jidami plain and the Jidami range, and at the old workings on the other side of that range. It evidently forms the ancient continental ridge into which the other lighter rocks were intruded. Several quartz-veins occur in it which have been largely worked, the ruins of a mining village being also present. The method of crushing the ore or quartz

Ancient workings near Jidami.

was evidently that of pounding the rock on a granite slab, and then rubbing it into powder by means of rubbing-stones chipped out of granite, numbers of which were found lying about. From the similarity which they bear to the rubbing-stones occurring at the ruins in Wadi Hammama, where rich samples of hæmatite were found, it is possible

that hæmatite was worked here. It may be stated that no visible gold was observed.*

The hornblende-granite has undergone considerable alteration, veins of epidote frequently occurring, and signs of solfataric action are also apparent, as tourmaline is present in the rock. **Jidami, Jarra etc.**

The red granite forms the hill-mass of Jidami, Jarra, and apparently 'Aradia, sending off-shoots into the hornblende-granite and into the metamorphic rocks. It is fairly coarse-grained, and weathers into steep-sided, rounded hills. All these hill-masses are intersected by dykes of quartz-felsite, 5 to 10 metres wide, which run in a north-west and south-east direction, and these in their turn are cut by dykes of a black doleritic rock. Thus, there have been two periods of movement, first, when the quartz-felsites were injected into the fractured granite along the north-east south-west direction, and later, a small movement allowing the thin dykes of the dolerite to cut the earlier quartz-felsite. This latter rock is strongly porphyritic and would make a good statuary stone. The later intrusive dolerites occur principally in the Wadi Sellimat where they form sheets and dykes.

The hill-range of Missikat el Qukh consists of the same granite as that of the Jidami-Jarra range. This granite extends a little beyond the Wadi Markh to the north, where it passes into the complex of rocks previously described. Further down the wadi, the granite is cut by numerous, irregular, narrow dykes of dolerite; while near the junction of the Nubian Sandstone and igneous rock it was replaced by a dark compact rock, similar to that on the junction-line in Wadi Jidami (see p. 224). In this rock compound dykes of granite and dolerite are present, which from this point stretch away to the northward.

A large portion of the central portion of the area is occupied by the drainage systems of Wadis Markh, Abu Shia, and Abu Zawel or Fatiri. This country, though only broken by one prominent range—Abu Shia—is nevertheless very interesting topographically and geologically, being composed of a parallel series of low sharp ridges and sandy valleys, the former owing their existence to dykes of quartz-felsite and dolerite which have been denuded more slowly than the quartz-diorite into which they are intruded. Some of these dykes are compound, veins of red granite occasionally forming the centre of a dolerite dyke. The dyke region of Abu Zawel, is separated from the plain of El Nagateir by the hill district of Hadrabia. The eastern boundary of this range consists of red granite of the coarse-grained type, enclosing **Low country of Abu Shia, etc.** **Importance of dykes in forming ridges.** **Hadrabia hills.**

* See Alford's report.

pieces of the more finely-grained quartz-diorite or hornblende-granite, which again shows that the former is younger than the latter. Where the wadi narrows, granite and dolerite come into close contact, but the basic rocks only form a secondary feature, and in many cases it is difficult to say to which class the rocks belong, as they appear to be intimate mixtures of acid and basic rocks. Cuttings have been made into them, and up a side valley, a number of mines have been noted, containing jasper and epidote, while in the valley itself one or two pieces of limonite were seen. It may be merely a coincidence, but it is noticeable that the iron ores are usually in the doleritic regions near their junctions with granitic areas. The low hills where the wadi widens out in the Hadrabia district appear to be basaltic, but on crossing the second pass a change takes place, a marked range of fine-grained red syenite running from this point to near the Nagateir plain, while the metamorphic series previously described (page 224) rests on its southern flanks. From this point, a very weathered porphyritic granite forms low ridges which disappear under the gravels of the Nagateir plain.

Old mines.

To the north of this district, near the point where Wadi Fatiri enters the Nagateir plain, the valley passes through a steep-sided ridge, consisting at the base of fine-grained doleritic rock, while on the summit is a thick sheet of columnar quartz-felsite which forms vertical cliffs of striking aspect. The columns lie in various directions, some showing in cross-section only, while in other places they stand parallel with the cliff. This rock forms numerous thin veins and sheets in addition to the large one just mentioned, cutting the altered doleritic rock in all directions, and lending a purplish tint to the hills. The ridge runs parallel with Wadi Fatiri for a few kilometres on the western side, and then bends away in a north-westerly direction towards the Abu el Hassan range. The columnar rock, however, is still represented by small sheets and numerous veins in the hill-ranges which form the foot-hills of Fatiri el Iswid, and which are continued almost up to Jebel Abu Harif.

Columnar quartz-felsite.

To the west of the columnar ridge the foot-hills are composed of a close-grained, black, altered dolerite in which occur wide dykes of quartz-felsite. This rock has a tendency to weather into thin slabs, which being full of cracks eventually break into small pieces. Towards the plain, the hills gradually lower and disappear for a time under the Nubian Sandstone and gravels. Further to the west, and about 8 kilometres from Jebel Abu Had, this rock reappears in a small black patch of low conical hills, which gradually lessen in size to the west, and disappear under the gravels. In it occur dykes of quartz-felsite, some of which are very coarse in texture, and contain curious crushed felspars.

About a kilometre to the north, there is another small exposure of this rock on the side of the gravel plateau, associated with it being another rock of an entirely different character, in colour looking like a white sandstone in the distance, but on near examination showing numerous small crystals of a clear unclouded felspar like sanidine. In general appearance and texture it is a trachyte. The relation of this rock to the sedimentaries is uncertain, as its junction with the underlying rock is masked by the gravel. One fact only is to be noted, viz., that the gritty sandstone at the base of the gravel plateau unconformably overlies it. **Trachyte in Nagateir plain.**

To the east of Wadi Fatiri or Abu Zawel, and stretching for many kilometres, this black doleritic rock forms a series of sharp ridges, these being due in many cases to the presence of dykes of younger dolerite and quartz-felsite. East of this appears a ridge of granite of the dark-red type crossed by dykes of magnetic dolerite, which cease abruptly at the compact dolerite of the Hadrabia district. To the north-west of the wadi, near the columnar rocks, the dolerite shews signs of shearing, this being probably due to the movement and strain engendered by the intrusion of masses of coarse dolerite. In this region there are, in addition, intrusions of a micro-granite and a dioritic rock seen in the wadi.

Passing to the north-east, the boundary of the doleritic rock is crossed, and the remarkable dyke country is entered. In this country the rock is a coarse, red, quartzose granite, with little mica, and standing out from it in relief is a series of parallel ridges, in the centre of each of which there is a dyke of fairly coarse dolerite or quartz-felsite. Bounding this district on the north side is a ridge of compact black dolerite, veined by the columnar quartz-felsite. At its extreme eastern end, an intrusion of fairly coarse granite has taken place, while on the opposite side of the wadi which separates this from Jebel Abu Harif, the latter is composed of quartz-diorite and coarse granite.

To the south and east of Wadi Fatiri or Abu Zawel, the hills in the immediate neighbourhood are composed of coarse red granite, which locally passes into a red micro-granite. From the point where Wadi Um Digal enters Wadi Fatiri this rock is replaced by a mica-diorite which forms all the low country up to the base of Jebel Um 'Anab, and bends round from this point westward towards Jebel Abu Harif. In character it is fairly coarse-grained, and contains a little quartz and hornblende, the former making it therefore a quartz-diorite.

Towards the east, quartz gradually increases in quantity in it, till beyond the watershed the rock becomes a mica-granite. In the region

just described, dykes of dolerite and quartz-felsite are very abundant, the general bearing of the former being north by east south by west, while that of the latter is east-north-east—west-south-west. The watershed ridge in this district is represented by the hills Ras el Barud, and Um 'Anab, both of which are composed of coarse, red, highly quartzose granite.

Diorite of Um Digal (Mons Claudianus).

At Um Digal (Mons Claudianus) as has been stated, the white micaceous granite, or diorite has been extensively worked by a method of wedging in series. Running through it are abundant dykes of quartz-felsite.

El Shayeb.

To the north of Um Digal the high mountain ranges of El Shayeb, and Abu Hamra, are, in the main, composed of the coarse-grained, red granite with little mica, which has been previously referred to.

The line of mountains from Fatiri el Iswid through Abu Harif, Abu Hamra, to El Shayeb forms the boundary, to the north of which is the main massif of the Red Sea Hills. The country lying northward of this line, and eastward of Wadi Qena, falls into three divisions, each determined by the character of the rocks composing it. The first division consists essentially of long, dark, sharp-ridged ranges running in the main north-east—south-west, but sending out long spurs at right angles to their general direction. These compose the chains of Fatiri el Iswid and part of Abu el Hassan, and consist of the metamorphic rocks and compact dolerites previously described.

Metamorphic rocks of Fatiri el Iswid, etc.

Central range near Um Disi.

To the north and north-east of these hills rise red mountains of the most varied form, consisting essentially of the coarse-grained granite of the El Shayeb type. In the deep gorge of Wadi Atilmi, this granite is plentifully traversed by veins of quartz, and masses of the same mineral are also distributed through it. In the valley itself are fragments of diabase, gabbro, and troctolite, which though not actually traced to their source, probably descend from the basic hills to the east. Here and there on both sides of the valley diabasic veins traverse the granite running normally in an east and west direction, and giving rise by their more rapid decomposition to deep vertical-sided gullies. Indeed, the high pass between the two peaks of Atilmi—the only break in a mountain wall from 1800 to 2000 metres high on the eastern side of the massif—appears to result in part from the decomposition of a vein of this nature. In addition to these, basic rocks have given rise to more prominent mountain-features, the long ridge and conical summits of Kohela, and Ghoza, being due to a thin film of dolerites and diabases overlying the granite. It is evident that, in a comparatively short period, these basic rocks will be entirely removed by

Granite traversed by diabase.

Dolerite and diabase on the summit of granite hills.

denudation, and it is a noticeable fact that the granite ridges in their immediate neighbourhood are of a very different type from the dome-topped mountains of Um Disi, where the granite has been much longer exposed to the influences of denudation. The inference cannot be avoided that these basic rocks are the last remains of a mass which once covered the whole of the granitic area.

Dolerite fringe at base of granite. An interesting feature in connection with this conclusion is the fringe of low hills of dolerite which runs close to the foot of the steep granite mountains, with but few breaks from a point south-east of Um Disi to the north-east side of the massif in Wadi Belih, this being possibly a remnant of the basic mass which has been faulted down.

Leaving the mountain chain at Wadi Atilmi, and passing through the dark doleritic foot-hills above-mentioned, a third type of country is entered, which, to the westward closely resembles the dyke-country of Abu Shia.

Dyke-country west of Um Disi. Near Um Disi are low foot-hills of a grey granite, into which veins of the red variety have been intruded. Leaving this place and passing westward along Wadi Um Yessar, the dark foot-hills on the north are composed of dolerites traversed by veins of syenite-felsite. Near the granite range of Um Disi, and on the south side of the above-mentioned wadi, the rock in places is a holocrystalline aggregate of plagioclase felspar and augite, and is provisionally classed as a gabbro. Its junction with the granite range is very abrupt, but the granite has intruded into the gabbro in broad red dykes (more or less columnar in aspect) containing fragments of the basic rock surrounded by a thick zone of secondary quartz. Doleritic dykes, on the contrary, stop abruptly when they come in contact with the granite.

Low dark range south of Wadi Um Yessar. To the south of W. Um Yessar rises a range of hills composed essentially of compact quartz-diorites and friable mica-granite much cut up by felsitic dykes. Associated with these is a grey granite with porphyritic, white felspar-crystals, while the syenitic felsite also becomes more porphyritic at the western end of the range. An interesting feature is the frequency of compound dykes, one side of which is red granite, the other grey diorite. Dolerite is also present, and in places fragments of the rock are embedded in the granite. To the westward a brilliantly-coloured red ridge is the first of a series of quartz-felsite and diorite dykes running almost due east and west, and penetrating the friable mica-granite.

Country between Um Disi and Wadi Qena. From here to Wadi Qena the country essentially consists of parallel dykes of the grey porphyritic granite, the friable, grey mica-granite, a grey diorite with spheroidal weathering, and a dark, greenish-yellow,

basic rock—a diabase—separated by narrow gravelly valleys. Near the mouth of Wadi Um Disi the granite hills become loftier rising 100 metres above the plain, the rock weathering spheroidally and containing much green mica, which forms dark lines on the sand lying on the sides of the ridges. At the deir in Wadi Um Disi, where the dolerites and granites come in contact, the latter show a very fine example of intrusion into the basic rocks.

Rocks bordering the Coast-plain. On the eastern side of the watershed the mountain masses of Jebel Um Kabbash, Abu Bedun, Moghat or El Mogher, Abu Morat, Marsala, Barud, and part of Nugara are all composed of the coarse, red, quartzose granite.

Between Jebel Um Kabbash, El Mogher, and Abu Bedun, there occurs a large area of low hills of altered hornblende-diorite or quartz-diorite which contains a large quantity of epidote.

Wadi Abu Garia. In Wadi Abu Garia, near the foot of Jebel Abu Garia, a large number of granite veins and bosses, as well as dykes and veins of a fine-grained dolerite are intruded in this rock. Quartz-felsite dykes are also present, running in a north of east, south of west direction. The granite is not the coarse red variety, but a friable white type with porphyritic orthoclase and a little mica, forming bosses which weather out into characteristic domes and rounded boulders. The diorite is evidently the oldest rock of the district, as it lies on the flanks of all the main ranges and receives veins from the rocks composing them.

Wadi el Mogher. Further south, the Wadi el Mogher passes through a plain composed of coarse red granite, which has evidently been faulted down from the main range. In this plain occur dykes of a remarkable labradorite-dolerite, 1 to 5 metres in width, and running in a north-west-south-east direction; many of the crystals are over 2·5 centimetres in length, and give the rock a peculiar dark lustrous appearance, the felspars also showing repeated twinning. These dykes persist to the south-east, being found as far south as Wadi Abu Morat.

Labradorite-dolerite with large crystals.

Associated with these are narrow veins of a different type of dolerite which also cut the granite in a more or less parallel direction. The granite passes under the beach deposits, which are composed of the rocks found in the surrounding country.

Jebel Barud.

The main granite hills are also cut by small veins of compact dolerite.

From this point to the Wadi Shalala the country is entirely composed of the coarse red granite bending westward into the large granite range of Barud. Between this wadi and Wadi Barud occurs an isolated hill* (part of the Barud range), which consists in the main of a coarse dolerite with large crystals of felspar and augite, likewise

* See Plate IV.

containing pink patches of a mineral which may be orthoclase or one of the zeolites. This rock has been intruded into the coarse red granite, which is only represented by a narrow strip near the centre of the hill.

Jebel Nugara is identical in structure with this mountain.

To the west of these two hills coarse red granite appears on their flanks, while still further westward stretching to the watershed, the grey granite or quartz-diorite occupies the whole of the low country from the Barud range to Wadi Safaja. In Wadi Um Tagher, 9 kilometres east of Jebel Abu Farad, the junction between the coarse red granite and this rock is displayed. Here the former can be seen cutting through the latter, and gradually taking its place, until at Jebel Um Tagher the grey granite is entirely displaced. Passing up Wadi Um Tagher, this rock passes in places into mica-schist, the latter alternating with a gneissose variety of the grey granite. This gneissose and schistose appearance is common throughout the district up to the watershed, veins of pegmatite and micro-pegmatite traversing it in all directions, while dykes of quartz-felsite and dolerite cut it, the first named giving rise to long parallel ridges stretching down to the neighbourhood of Wadi Barud, and the basic rocks run in a north and south direction, but seem to radiate also from a definite point near Ras El Barud.

Gneissose character of the granites.

Parallel ridges of quartz-felsite near Barud.

These quartz-felsites are of two kinds, one, the ordinary type met with near the western side of the watershed, while the other (the more important on this side), is a hard, dark-blue rock, ringing under the hammer, and weathering brown at the surface. Looked at from a distance, it might be mistaken for a dolerite, but examination of a hand-specimen reveals quartz-crystals among its components. Near the watershed is the range of Abu Farad, which is composed of the coarse red granite. Towards the south, the grey granite becomes finer-grained, and takes on the character of a quartz-diorite. It occupies the low country behind Jebel Safaja and Abu Diab as far south as the boundary of the district a little north of the Duwi range, where it appears to pass into a diorite.

Jebel Safaja, etc.

The main mountain-ranges of Jebel Safaja,* Abu Diab, and Jebel Saga are composed of coarse red granite, the same as in the older main mountain-systems of the range.

Jebel Agharrib.

Besides the main masses of granite above-described, there are several isolated hills of the same rock rising through the dolerites, etc. The principal of these is the Agharrib range, a mountain-mass rising 427 metres above the Wadi Saga. Hornblende-granite forms low knolls at its base, and the main peak consists of the same rock, weathering

* See Plate III.

spheroidally and containing large crystals of quartz. Here again are some interesting cases of double dykes, a compact grey rock 1 metre thick intruding into the granite, and having in its centre a vein of red granite 3 metres thick. Another mountain of pink colour was also seen to the west of Wadi Semna, repeating the outlines of Agharrib, so it may safely be concluded that the rock composing it is a similar hornblende-granite.

Summary. Briefly, the observations made on the igneous and metamorphic rocks are as follows:—

1. The Metamorphic are older than the Igneous Rocks.

2. The gneiss of Meeteq is the oldest member of the metamorphic series, the schists coming next in order, followed by slates, altered ash, sheared diabases and dolerites, etc., these being overlaid by—

3. Compact Dolerites exist in sheets and masses of great thickness, both to the north (Fatiri el Iswid) and south of the district (Wadi 'Esh), also in fringes round the main granite-mass of Um Disi, Abu el Hassan, etc., and capping the same in Kohela and Ghoza.

4. Grey-Granites and Quartz-Diorites, often gneissose, form the main mass of the low country of the northern and eastern sides of the sheets.

5. Red Granite gives rise to the main mountain-ranges, and forms the backbone of the country to the north and east.

6. Quartz-Felsites and Dolerites occur in dykes and sheets, the first-named producing a system of parallel ridges, especially in the low country formed by No. 4.

7. Wherever they meet, these rocks are unconformably overlaid by the Nubian Sandstone, or younger beds of the Sedimentary series, so that they are at least Pre-Cretaceous.

8. The final elevation of the Red Sea Hills is probably late Pliocene or Pleistocene, rocks of the latter age being found on the sides of the hills, while the main mass has been faulted down, giving rise to a flat plain at their base.

Igneous and Metamorphic Rocks north of latitude 27° N.—While south of the mountain-barrier of El Shayeb, Um Disi, etc., the junction of the granite, dolerite, and metamorphic rocks is irregular, north of these ranges there is a remarkable symmetry, accompanied by an abrupt change in the surface geology. Thus, on leaving Um Disi, and going northward towards Wadi Gattar, the road is for the greater part of the time coincident with a geological boundary, the red granite hills rising in steep precipitous slopes 600 metres above the valley on

the eastern side, accompanied at their base by a dark fringe of more basic rocks (mainly dolerite and syenite-felsite dykes) while on the west there are only a series of low parallel ridges due to dykes of grey and red quartz-felsite, which terminate suddenly close to the mountain wall. One of these ridges is especially characterized by its brilliant red colour, and north of it diorite dykes are as frequent as the quartz-felsite, while near it the dolerites pass into a gabbro.

In latitude 27°·6′ N. the granite ridge suddenly bends back sharply at right angles to its previous course, this change being accompanied by a striking alteration in the geological character, the hills composing the range of Jebel Dokhan on the north of Wadi Belih being basic and metamorphic. If now some point* in the eastern plain be taken from whence the whole of the northern Red Sea Hills are visible, the relations of the various members to each other can be more clearly traced out. It will be seen that three main divisions can be recognized in the hills. (1) A red granite, which, forming the high mountain-system rising precipitously above Wadi Belih, and then broken in places by longitudinal valleys, extends more or less east and west from J. el Shayeb to J. el Oman. North of Wadi Belih, the granite is more broken, and runs in a north-south direction, but rises to over 1500 metres in the serrated ridge of Abu Harba and is again seen to attain considerable elevation in the peaks of Miuselman and Mellaha. Granite ranges do not reappear again until in the extreme north of the district, where the granitic crests of Dara, and beyond our area, the still more striking peak of Gharib, form two of the most prominent features in the Northern Red Sea Hills. (2) In front of the Gattar range, and fringing it extends a line of low, dark hillocks, which are here the sole evidence of the presence of basic rocks, but in the northern-trending ranges, the latter are of special importance, as they not only attain heights of over 1500 metres in Dokhan, but continue as a prominent range, or series of ranges forming the front of the hills as far as Jebel Mongul, and then when Dara takes that position, pass behind it, giving rise to an apparently parallel ridge. (3) Finally, in front of these are lower foot-hills of grey, gneissose quartz-diorite or granite, which by the weathering out of the dykes have given rise to the characteristic dyke-country scenery.

Metamorphic Rocks of Jebel Dokhan, etc.—A cursory examination of the hills to the north of Wadi Gattar at once shows that the beds composing these are complex, the western foot-hills consisting of dolerites and tuffs, granite also being intruded into them. In the small valleys which run together to form Wadi Gattar, the rolled pebbles are of varied nature including quartz-felsites, diabases, por-

Metamorphic rocks north of Gattar.

* See Panorama I.

phyrites, tuffs (some of the latter of purple colour). On crossing the watershed into Wadi Belih, while red granite forms the southern wall, a thin belt of dolerite resting at its foot, the gentler slopes of the north are occupied by dolerites, which form thick sheets, overlying one another, separated by schistose beds and tuffs, the latter being very common. In one of the wadis at the back of a Roman Deir south of Dokhan, these basic rocks became increasingly porphyritic, and were in many cases interveined with granite.

In the southern spur of Dokhan, the sheets of dolerite are well displayed, an intruded mass of granite separating it from a long straight crest—the Figari-Berg of Schweinfurth—in which the vertically-running felsite dykes are especially striking. The main range at the base consists chiefly of granite, but above the pass leading to the porphyry quarries, the rocks are first conglomeratic in character, while the summit itself is composed of a dark porphyritic andesite. On the northern side of the pass the porphyry is alternately interbedded with felsitic or micro-granitic dykes so that the whole mountain-side seems to consist of an alternation of purple and red bands.

This rock has been the subject of a very complete monograph by Dr. Oskar Schneider, entitled "*Über den roten Porphyr der Alten*", enclosing an excellent map of the district together with a panorama (both by Dr. Schweinfurth) and has also been visited by nearly all the principal travellers in the desert. Wilkinson, Lepsius and Schweinfurth are amongst those who have contributed the most to our knowledge of its occurrence. It is, in the writers' opinion, in the main an andesite containing withamite* having a crystalline matrix of a brownish-red to purple colour, through which are scattered innumerable small white lath-shaped crystals of plagioclase felspar. Some of the blocks in the valley showed well-developed banded, or fluidal structure, while in places it is brecciated in a remarkable manner, the fragments being practically of the same nature, both chemically and petrographically, as the rock in which they are embedded. This structure was specially investigated by Rutley † who came to the conclusion that it is due simply to crushing. Attention may also be called to the important work by Delesse on specimens collected by Lefevre. ‡ This writer has more especially attacked the question from the chemical point of view, both examining the ground-mass, which had a specific gravity of 2·765,

* Manganese-epidote.

† *Quart. Journ. Geol. Soc.*, Vol. XLI, p. 157, 1885.

‡ *Bull. Soc. Géol. France*, ser. 2, t. VIII, pp. 484-524, 1850.

and the rose-red crystals characteristic of the rock. The results are as follows :—

Ground-mass.		*Crystals.*	
SiO_2	62·17	SiO_2	58·92
Al_2O_3	14·71	Al_2O_3	22·49
Fe_2O_3	7·79	Fe_2O_3	0·75
CaO	3·30	Mn_2O_3 ?	0·60
MgO	5·00	CaO	5·53
Na_2O	4·10	MgO	1·87
K_2O	2·04	Na_2O	6·93
Loss on ignition... ...	0·58	K_2O	0·93
	99.69		99·67

They thus differed in his view from most felspars in the greater amount of the MgO, and he placed them in an intermediate position between oligoclase and andesine. In addition to the felspars and manganese-epidote, dark hornblende, iron oxide (possibly hæmatite) and magnetite, are also present. Schneider also refers to the winding veins of quartz, which meander through the rock and terminate in the most delicate threads. Rosenbusch* calls attention to the beautifully-crystallized apatite crystals in the rock, and to the plagioclases, which for the most part are seen to be altered to a mineral which is of reddish colour in ordinary light. This alteration product was subsequently recognized by Liebisch † as being very closely related to the epidote-like mineral, withamite, discovered by Brewster in the porphyrite of Glencoe, in Argyleshire, while von Lasaulx went a step further in stating that there was no doubt that compact tuffs must also be included under the general term of *porfido rosso antico*, having the characteristic colouring. In the present memoir it is claimed that these rocks are part of a great metamorphic series, and not, as hitherto held, dykes of igneous rocks penetrating an Archæan mass, though the latter are so frequent that it is not easy to say at any one spot which is the dyke and which the parent rock. If time and circumstances permit, the numerous specimens brought back by the Survey will be submitted to a close petrographical analysis, with a view to determining the question as to the origin of the manganiferous colouring material.

Putting aside minute details, it may be generally stated that the Dokhan ranges, as well as those of Um Sidri, Um Messaid, and Kufra ‡ appear to have their summits formed of lavas of andesitic type, small white felspars being scattered in a greenish or grey matrix, while the base is composed of granite. The question that now presents itself is

* *Mikroskopische Physiographie der massigen Gesteine*, Stuttgart, 1877, p. 290.

† *Zeitsch. Deutsch. Geolog. Gesellschaft*, Bd, XXIX, 1877, p. 717.

‡ Panorama I.

whether the granite or the overlying lavas are the older, a point which requires a special mention in view of the fact that in a well-known work,* it is stated that the *porfido rosso antico*, or imperial porphyry (which appears in part at least to be an andesite containing withamite) is a dyke 20–25 metres thick in the granite of Jebel Dokhan, whereas on the contrary dykes of granite, dolerite, and quartz-felsite cut this rock. Though all that has been stated hitherto goes to show that in reality the granite is the younger rock, conclusive proof is forthcoming in Wadi Um Sidri, where some very interesting cases of intrusion have been observed.

Granite intruded into Volcanic series. Thus close to the pass leading into Wadi Um Messaid a dyke of red microgranite running in the andésite has for a time prevented another vein of grey granite from penetrating into the lava, but finally after running parallel for a short distance, the latter succeeded in bursting through, and sent long veins and branches into the porphyry.† Some of the small granitic veins have been subsequently trough-faulted. The granite itself belongs to the gneissose, low-country type, and is traversed by north and south-trending dykes on the western side of Wadi Um Messaid, while on the east the ridges consisting of diabase and red granite, run south-east and north-west, but the two systems do not appear to meet, the valley separating them.

From the general appearance of the hills, it has been inferred that portions of the Mellaha and El Adid el Gadan ranges are equally formed by the andesitic series, but the Red Sea Hills were not again specially examined until, on the return journey from Jebel Zeit, a halt was made at the foot of Jebel Dara. On approaching the hills at this point, on leaving Bir Abu Nakhla, low sedimentary ridges are first passed through, followed by a broad plain out of which rise isolated hills of Nubian Sandstone. This plain is bordered on its western side by a low but well-marked red range of highly quartzose granite and quartz-felsite, in front of which are low dark dioritic or doleritic foot-hills. The granitic country extends up to the spurs of the Mongul range, in which the rocks are of peculiar character, apparently fine-grained granulites, alternating with diabase and ferruginous beds.

Judging from the specimens found in the valleys, it was evident that porphyritic andesites or porphyrites, similar to those of Dokhan, are present in the eastern spurs of Jebel Mongul. In addition to these, crushed and schistose dolerites are common, and slates are present in the foot-hills, while the whole base of the mountain is formed of granite, which sends veins into the overlying basic and and metamorphic series.

* Rosenbusch's, *Physiographie der Gesteine*, p. 472.

† The term *porphyry* is here applied to the porphyritic andesites and the manganese-bearing variety.

On the northern side of the Dara* valley the conditions are totally different, metamorphic rocks being entirely absent in the Dara granite range, which rises in a series of sharp ridges. The term of Jagged Razor hill, given on the Admiralty map, shows the impression which these leave on the mind when viewed from a distance. As far as observed, the granite composing this range is a hornblendic variety.

After visiting the northern end of the Mellaha limestone range, the igneous region was again re-entered up Wadi Dib, the foot-hills which border the Nubian hills at this point being composed of a series of porphyritic andesites, porphyrites, probable tuffs, and an interesting agglomerate consisting of intermingled granite and andesite ("porphyry") pebbles, sometimes 15 centimetres in diameter. Behind them the foot-hills are granitic; these as they rise higher to the east become more and more veined with hæmatite-bearing quartz-veins, which some way up Wadi Dib had been (at any rate superficially) worked out. Further up the wadi, hæmatite veins have not been noted, they being replaced by low, dyke-ridge country, diabase veins running east and west through the hornblende-granite, which with a diorite forms the main rock. Further on, low ridges of a greenish-grey tint flank the higher spurs of Mongul and Dib, these being mainly composed of dolerite and diorite, while through them run numerous veins of carbonate of iron. The granite here was again much veined, the latter containing much hæmatite associated with a meshwork of quartz-crystals, and on the other side of the hill with barytes, while good carbonate of iron also forms some prominent dykes in the same neighbourhood.

Porphyritic andesites and agglomerate of Wadi Dib.

Still further up, the veins of chalybite cut through the hill in all directions, but especially north-east and south-west, being also often accompanied by bands of hæmatite, while in a foot-hill north of the valley, micaceous hæmatite had been dug out of holes, and was lying in sparkling blocks round their edges. These have been analysed by Lucas, yielding the following results:—

Hæmatite of Wadi Dib.

	A	B
Water and matter volatile at 100 C....	·01	·13
Organic matter and carbon dioxide	·50	·78
Silica and insoluble matter	21·27	21·07
Ferric oxide with a little aluminium oxide	77·99	75·94
Calcium oxide	·50	1·22
Magnesium oxide...	Trace.	Trace.
Phosphorus pentoxide	·04	·03
Sulphur trioxide	—	Trace.
	100·31	99·17

* Panorama II.

Lucas has added the following analyses of two typical ores for comparison:—

1. Ore from Ulverstone, Cumberland.
2. Ore from Lake Superior.

	I	II
Water and organic matter	—	1·09
Silica and insoluble matter	6·55	3·27
Carbon dioxide	2·96	—
Ferric oxide	86·50	93·75
Manganous oxide	0·21	Trace.
Aluminium oxide	—	0·73
Calcium oxide	2·77	0·61
Magnesium oxide	1·46	0·23
Sulphur	—	0·03
Sulphur trioxide	0·11	—
Phosphorus pentoxide	Trace.	0·32
	100·56	100·03

It will thus be seen that the balance is against the Egyptian ores, but it must not be forgotten that the former are from surface specimens, the impurities being almost entirely silica, while the latter are selected ores from long-worked centres.

Calc-schists, etc., and marble at Wadi Dib.

The main rock of this district appears to be a diorite, associated with granite and dolerite, but on reaching a plain from which the road branches out in four directions, there is a change in the geology, calc-schists first making their appearance, and then a saccharine marble, mainly of a grey colour, but still in sufficient quantity to be workable. The marble occurs in several masses, running roughly parallel to the valley, and in places interstratified with mica and hornblende-schists. These metamorphic rocks apparently lie between Wadi Dib and the El Urf range, and are cut by red felsite-dykes running north and south, while they are seen to be underlaid by masses of granite and mica-diorite. In the time at our disposal, it was impossible to arrive at any broad conclusions as to the distribution and relations of the metamorphic rocks.

Metamorphic rocks in Jebel el Urf.

The El Urf chain at the point crossed was composed of three groups of hills, the first consisting of low, grey foot-hills being doleritic, the second, a yellow-coloured range, apparently consisting of felsites only, while the third, and highest, had at its base a greenish-coloured felsite with red felspars, and a purple porphyrite, which looks identical with the imperial porphyry of Dokhan, but contains no withamite and is the source of the purple blocks which form a striking feature among the

Imperial porphyry in El Urf.

pebbles in the upper part of Wadi Dib. The summit of the range ascended was composed of a well-marked agglomerate, containing amongst other fragments pieces of imperial porphyry.* Up a narrow gully to the west the beds were seen to be standing almost vertically, while for some distance the hills on both sides of the valley seemed to be composed of a boulder-agglomerate similar to that seen at the entrance of Wadi Dib, the eastern summit being crowned by the green-coloured felsite with red felspars above-mentioned. On the northern side of the range the lower hills on the eastern side are composed of stratified rocks, dipping 10° east-of-south into the range, and consisting of very fine-grained, siliceous-looking rocks, accompanied by slaty varieties, these being in some places much folded. These appear to be overlaid by the andesites, while underneath are compact quartzose rocks. In Wadi Dara itself the metamorphic rocks disappear, the mica-diorite at the base occupying the whole area, but to the north rise high dark purple hills, probably geologically of the same structure as the El Urf chain, in which the strata are dipping strongly to the eastward at the base, apparently due to faulting parallel to the main chain. These basal rocks are stratified and of doubtful character (possibly ash), above them being bright green tuff and amygdaloidal lava, these again covered by a purple lava (? andesite), while above all are red felsites in some of the hills, and red porphyrite in the principal dark summits at the back of the Dara chain. A longitudinal valley, or rather furrow, separates these hills from the granite range of Dara, which consists of several north and south ridges parallel to one another, the granite being very much dyked.

Agglomerate in El Urf.

The parallel Ranges of Jebel 'Esh† and Jebel Zeit.—Turning now to the isolated and parallel ranges of Jebel 'Esh and Jebel Zeit, it is at once seen that they are evidently parts of the main igneous mass which have been detached by the main line of fault which runs up the eastern flank of the Red Sea Hills. When examined in detail, they are found to be composed of rocks the counterpart of which can always be found in the main igneous range opposite. Thus in Wadi 'Esh imperial porphyry is met with, and the main mass of the range is composed of an augite-andesite. These are exactly paralleled in Wadi Um Sidri where a big mass of augite-andesite forms the main rock, and at its head occur the famous quarries of the "Porfido rosso

NOTE.—Just outside the area Guereb appears to be mainly composed of a fine-grained syenite, while the Gharib granite shows beautiful examples of compound basic dykes.

* In reality *breccia verde antico.*

† Panorama III.

antico." Bosses of red and pink granite also occur in these ranges (Jebel Zeit, except for a mass of quartz-felsite, being entirely composed of these in its igneous part); while dykes of quartz-felsite and dolerite are found crossing them in directions approximately at right angles.

Previous to the formation of the Geological Survey in 1896, these ranges, together with the eastern part of the main hill-range, were described by L. H. Mitchell.* In this report, after describing the rocks correctly, except for a difference in the nomenclature, he says the range of Jebel 'Esh consists of syenite, capped in many cases by a mass of porphyry. In the southernmost part he finds no evidence to show which of these two rocks is the younger, but in the mass of Jebel Abu Had he finds veins passing from the syenite into the porphyry. When, however, he endeavours to assign a definite age to these rocks he gets into hopeless confusion. By misunderstanding the appearance of the junction between the granite and the limestone which he calls Upper Miocene, he makes the former younger than the latter, although on close examination pebbles of the former are found forming a conglomerate at the base of the latter. Again at Bir Mellaha, he finds the Nubian Sandstone lying on the granite in such a way as to show that the latter is older than the former! There is thus a great discrepancy between the two statements, and a wide margin is given to the reader on which to form his own estimate of the age of this rock.

The case of the porphyry is quite as confusing. At Jebel Abu Had the Upper Miocene is said to be younger than the porphyry; while in a narrow gorge between Wadi Mellaha and Jebel 'Esh this same bed is made older than the igneous rock, it being asserted that the latter has fused and altered the former; and finally in Abu Sha'ar, the former is said to be deposited on the latter and to contain pebbles of it. An anomalous state of things is thus shewn to exist: the limestone which is regarded as Miocene is older than the porphyry, which in its turn is older than the granite, a conclusion which is obviously absurd, since it makes the granite to be formed in very recent times.

The ridge of Jebel Zeit, in the work under discussion, is dismissed in less than a page, and it is stated that the granite there also is younger than the Upper Miocene, a conclusion which is glaringly wrong, as the Nubian Sandstone is seen to rest on the eroded surface of the igneous rock.

Work of the Survey.

These two ranges were first visited by the Geological Survey Officers in December, 1896, and were hurriedly examined during a stay of

* "Report on the Geology and Petroleum of Ras Gemsah and Gebel Zeit," 1887.

eight days, three rapid traverses being undertaken with the view of determining the structure of the country in relation to a probable supply of petroleum. During that time, the southern half of Jebel Zeit, Ras Jemsa, and the hill-ranges of Jebel 'Esh and Mellaha between Bir Mellaha and Wadi 'Esh were examined. These ranges were again visited by two Survey parties in the spring of 1898, when the whole of the rocks were practically seen in the various traverses then made.

The range of Jebel Zeit* runs parallel with the sea-coast from the Bay of Zeit to Ras Dib, a distance of 20 kilometres, and stands above sea-level from 260 to 460 metres. At its southern end it is entirely sedimentary, the core of igneous rock first appearing opposite the buildings near the petroleum wells. On either flank of this rock, the sedimentaries lie tilted at various angles, this disturbed condition being due, not to the intrusion of the former into the latter as stated in the work above-mentioned, but to a subsequent upheaval, the igneous rock being older than the sedimentaries. **Jebel Zeit.**

Beginning at the southern end of the igneous mass, the hill called Jebel Zeit proper is formed of a dark green felsitic rock with specks of quartz scattered in it. This forms the first patch of igneous rock visible, and rises in steep angular ridges up to the peak, which is 260 metres above the sea, and forms a black conspicuous hill. It is found on examination to consist of granitoid quartz-felsite, *i.e.*, quartz-felsite with basic portions, forming the main mass, and a micro-granite with patches of a green hornblende present as north and south-trending dykes.

In the small wadi which comes out of the range near the foot of Jebel Zeit proper, there is a dyke of quartz-augite-diorite about 8 metres wide, running north and south, and parallel with it is another of quartz-hornblende-diorite of smaller size. Besides these there is a set of basic dykes running W. 20° S., consisting of diabase, ophitic dolerite, and dolerite with epidote.

Beyond this to the north, where a fault has let down the gypsum and exposed the igneous core, there appears a new mass of rock which in hand-specimens looked very dark and basic in appearance, although shewing some quartz, and under the microscope proved to be graphic granite. It is also cut by east-and-west basic dykes. This same rock is again met with in a wadi further to the north, and is found under the microscope to contain a good deal of indicolite, which accounts for its dark, much altered, basic appearance. Associated with

* See Plate VII and Panorama IV.

this is a coarse red, very quartzose granite in which the felspar is changed into microcline. Beyond this comes graphic granite shewing good micro-pegmatite, the next in order being a quartz-diorite.

To the north the rest of the igneous rock is all coarse red granite similar to that described. In an isolated mass in a wadi to the west of this mass there is a curious brecciated rock which in section proves to be a micro-granite.

From observations made it seems that the coarse red granite with the graphic variety is the oldest rock here, the micro-granite and quartz-felsite of the southern peak being next in age, as they send veins into the former. The relations between the two sets of dykes is not so clear, but reasoning from analogy the basic set is the younger.

In this range there is abundant evidence of earth-movements in the structure of the rocks composing it. Graphic granite which only occurs in a region of movement such as the neighbourhood of a fault, seems to be the main rock in the range, while the evidence of the felspars changed into microcline also points in the same direction. The presence of indicolite also shows that there must have been an emission of gases producing solfataric action, boracic acid having formed this mineral by its action on the felspars. This gas must have come up some fissure or fissures in the earth's crust, and this agrees entirely with the deductions made from the examination of the country. It is thus interesting to find that both the stratigraphical and petrographical evidence point to the conclusion that there is a line of fault running along the seaward side of this ridge.

Jebel 'Esh. This range extends from the plateau of Abu Sha'ar on the south to where it joins the foot-hills of the main Red Sea Hills, near Bir Abu Nakhla, a distance of about 56 kilometres, and runs parallel to the limestone range of Mellaha, and that of Jebel Zeit. Viewed as a whole, it is essentially a ridge of volcanic rocks, into which granite has been intruded in the form of three small bosses, viz., at the mouth of Wadi 'Esh, Jebel Um Dirra and Wadi Mellaha,* and Jebel Abu Had, and varies in height from 300 to 410 metres. It was crossed at four points by the Survey parties, viz., Wadi 'Esh, Wadi Um Dirra, Wadi Gemalein, and Wadi Abu Had; while its flanks were examined from the first-mentioned wadi on the south to the last-named on the north.

On its seaward side it has, at different points, a patch of coral limestone laid on to its flanks, which at one or two places caps the igneous rock, as at the mouth of Wadi Mellaha, and Jebel Abu Had,

* See Plate V and VI, and Panorama III.

while on its western side the Nubian Sandstone lies in places well up its flanks. It is cut by numerous doleritic dykes and veins running in a northerly direction, while quartz-felsites break through it in an east and west direction.

Commencing at its southern end, it is seen to consist of ashes and agglomerates on its western side, followed by glassy andesite, which gradually becomes more crystalline as it is followed towards the centre of the range, crystals of augite being visible in the hand specimen; the rock assumes the characters of a porphyrite, and in one place at least has been changed into imperial porphyry. The characters of the andesite remain constant throughout the length of the range. In Wadi Gemalein, on the eastern slope of the range, agglomerate and ash occur at the level of the ground, and are also met with on the western side at various places.

Granite. At the eastern end of the gorge of Wadi 'Esh the first mass of granite shows itself. Here the relations are different to those observed between the volcanic and plutonic rocks at all other places in the Red Sea Hills, as there is a zone of decomposed rocks at their junction, no veins being observed to pass from the latter into the former, the inference being that the granite is older than the andesite. This first area is only a small one.

In Jebel Um Dirra there is a larger exposure extending right across the range from east to west, and forming a mass of low hills round Wadi Um Dirra. Numerous dykes of quartz-felsite running north-of-east and south-of-west, and doleritic dykes and veins having a north and south bearing, cut this granite, but no evidence of intrusion of this rock into the andesite was seen. This patch extends a little distance to the north of Wadi Mellaha, ending about a kilometre south of the entrance to Wadi Gemalein.

Along the west side of the range there is an intrusion of a sheet of porphyritic dolerite or andesite,* which extends about a kilometre and a half, but dykes of the same rock are met with in the andesite in Wadi Belih.

The last area of granite occurs in Jebel Abu Had where it is seen to send veins into the andesite and thus proves itself younger than the volcanic rock.

The two masses of granite at the mouth of Wadi 'Esh and in Jebel Um Dirra are the only exceptions to the rule that the granite is the youngest of the rocks forming the mass of the hills. These may be

* See Section I.

only apparent exceptions as a close search all along the junction might reveal an intrusion of it into the andesite.

This range, together with that of Jebel Mellaha, is unique on account of the transverse "Rift Valleys" which pass through it, *e.g.*, Wadi 'Esh, Wadi Mellaha, and Wadi Abu Had.

Summary.—Whatever may be the final conclusion as to the precise succession of the non-granitic igneous rocks, it is clear that volcanic action has been as active north of latitude 27° N., as it has been south of that line, andesites, dolerites, ashes, tuffs, and igneous agglomerates having now been shown to extend from the former latitudes to 28° N., or over a distance of nearly 100 kilometres. Their age with regard to the granitic and dioritic masses is also clear,* as it has been constantly stated in the preceding pages that the granite has sent veins into the more basic rocks overlying it. On the other hand, beds which suggest a sedimentary formation apart from volcanic action are of the rarest description, and are indeed limited to the marble and calc-schists associated with hornblende and mica-schists noted at the head of Wadi Dib, whose relations to the volcanics at present remain undetermined.

There are, in addition, some very interesting relations observable when this portion of the Red Sea Hills is viewed as a whole, certain broad, topographical, geological, and scenic features changing at the same time. The first point to be noted is the successive advance of the Red Sea Hills eastward. Thus the main range of Dara † runs a little west of longitude 33° E., until the main Wadi Dara is reached. Here two things happen, the granite chain of Dara ends abruptly, and a transverse chain of porphyry (El Urf and Mongul) extends forward to about 33° 3′ E. This transverse range marks a great topographical change, every longitudinal ridge on the northern side coming abruptly to an end.

Thus the Dara type of parallel north and south ridges, the granitic hills being to the east, and the volcanic to the west, comes to an end at a transverse porphyry chain. There is now a new district, which from Wadi Dib may be called the Dib type. The eastward front of the Red Sea Hills again becomes longitudinal south of Mongul, the heights of El Adid el Gadan (composed of "porphyry"), running almost due north and south in longitude 33° 3′ E., but to the west the country is only composed of comparatively low granitic and dioritic hills intersected by sandy plateaux and valleys. Roughly speaking in latitude 27° 30′ N. a second broken transverse chain (apparently volcanic or metamorphic),

*See possible exception in Wadi 'Esh p. 245 † Panorama II, and Plate II.

the Sobeir-Mellaha group, accompanies Wadi Abu Had, and the front of the hills is again advanced about four minutes eastward, while instead of there being only broken hills behind the prophyry range, the summits of bold granite peaks are seen, and the granitic ridges towards Wadi Qena show remarkable east and west parallelism, in many cases forming important hill-masses, such as those of Gialla and Guberat Ghanam. Wadi Abu Marua marks the last great change, the hill front being formed by the north and south trending chain of Dokhan and Um Messaid, which is in longitude 33° 15′ E., and again is almost due north and south, but is terminated abruptly at Wadi Belih. That is to say there is practically not one continuous north-south-trending volcanic range, but four, each one to the south being a little in advance of the others to the east, and generally speaking increasing in height southward, the change taking place in each case at a point where a transverse chain runs at right angles to the main direction.

Thus recapitulating, Dara porphyry range, about 900 metres, in longitude 32° 50′ E., is cut off by Jebel El Urf. Mongul-El Adid el Gadan range, 900-1200 metres, longitude 30° 3′ E., is cut off by the transverse range of Jebel Mellaha and Sobeir, and Wadi Mellaha. Lower porphyry hills (no name), in about longitude 33° 10′ E., are cut off by Wadi Marua. Dokhan-Um Messaid range, 1500-1800 metres (main peaks), in longitude 33° 15′ E., is cut off by Wadi Belih. South of Wadi Belih, the volcanic series of the Dokhan type practically disappears altogether, as far as our present experience goes, except in low foot-hills.

Granites and Diorites.—As has already been stated, the remainder of the Red Sea Hills, north of latitude 27° N., are composed of rocks of granitic or dioritic nature, the higher ranges being more typically granites, while the lower foot-hills generally show traces of foliation, and are thus distinctly gneissose. It has also been stated that this granite in all the cases examined is seen to underlie the volcanic rocks, and in the main Red Sea Hills is intrusive into them. Several of these ranges have been examined, and their characteristics will now be briefly described.

*Jebel Abu Harba.**—Wadi el Atrash, running north and south, and beginning about latitude 27° 20′ N., longitude 33° 10′ E., is in its upper course bounded by the granitic slopes of Abu Harba and El Atrash, the former rising 900 metres above the valley in a precipitous and serrated ridge, and terminating abruptly in latitude 27° 15′ N. This mountain itself is composed mainly of the coarse-grained red granite with little mica, which is the common constituent of the high

* Panorama II.

ranges from J. Gattar to J. el Shayeb, and of a second type, a light-grey variety with large red and white porphyritic felspars. A remarkable feature in this hill (also seen in Gharib and Dokhan) are the red felsitic dykes running up the sides and over the crest of the mountain, and standing out in prominent ridges, while parallel to them run gullies, due to a dark, fine-grained, diabasic rock, easily flaking in a concentric manner, and thus resulting in a typical spheroidal appearance.

While on the eastern side the granite range ends abruptly, low hills of the volcanic series taking its place, on the west it extends much further south, forming the conspicuous range of Abu Hamra, which rises about 300 metres above the valley, and is composed on the outer edge of a fine-grained hornblende-granite, while the lighter El Atrash range behind and north of it is formed of a more micaceous variety. Here again, as in Abu Harba, the dykes are very noticeable, dolerites and felsites being in many cases closely associated in compound veins. At its southern end this range is composed of a granitic rock (containing mica, together with white and red felspars), in which are abundant veins of quartz-felsite and fine-grained diorite.

All the country south of this range consists of an apparent maze of low hills, but from a height these are seen to consist of dykes of quartz-felsite, etc.., (mainly running east and west) rising through a very friable granite rapidly undergoing disintegration. In fact it may be stated generally that south of latitude 27° 10′ N., from Wadi Qena up to the boundary of the Fatiri el Iswid metamorphic rocks and the granitic hills of Um Disi, the low country consists of a series of parallel dykes, in which the following rocks repeat themselves with monotonous regularity, viz., grey porphyritic granite (Abu Harba type), ordinary grey, micaceous, (biotite) friable granite, fine-grained diabase with spheroidal weathering, and a darker dolerite, these often running parallel to one another in the same ridge. In addition to these, quartz-felsites and syenite-felsites make their appearance, especially towards the east. The grey granite or quartz-diorite is apparently the fundamental rock of the district. Many local variations have been noted, but as their meaning is not clear, these will only be briefly referred to. The principal are these:—The dark range bordering Wadi Um Yessar to the south consists fundamentally of quartz-diorites dyked through and through by fine-grained felsitic rocks and dolerites, the syenite-felsites becoming very porphyritic at its western end. Where more basic rocks are present, the dykes of quartz-felsites disappear, while syenite-felsites take their place. A noticeable point is the frequency with which a red granite dyke is in absolute contact with and parallel to

one of dolerite. The low hills forming the western flank of the Red Sea range and Wadi Dib are again composed either of the grey friable micaceous granite or of diorites which have been locally crushed, producing rocks which may be termed gneisses, the whole dyked and veined. Here quartz-felsites are not so abundant as on the western side, the basic veins being more conspicuous. At the northern end of the district Jebel Dara is composed of a hornblende-granite. The essential point is the fact that the granites and diorites are intrusive into the volcanic series, and that they are dyked through and through by both acid and basic veins, in a larger number of instances running east and west.

General Recapitulation.

We are now in a position to give the general succession for the region. The oldest rocks are undoubtedly:

1. The Metamorphic Series of Jebel Meeteq consisting of (beginning from below) gneisses, schists, altered ash or slates.

2. Volcanic action had already begun during the period of formation of the grauwackés and slates, as sheared diabases and dolerites are in places closely associated with them, but the main mass of the dolerites is younger than the slates. Thus, the next in succession is a Volcanic Series, in the south consisting mainly of dolerites and sheared diabases, and in the north of dolerites, andesites, tuffs, and agglomerates.

3. These are themselves underlaid by and in most cases intruded into by a third series, a quartz-diorite or grey granite, in many cases gneissose.

4. Through the volcanics and grey granite rise masses of red granite, which possibly are almost contemporaneous with dykes of quartz-felsite and dolerite, piercing through the members of the preceding series.

5. These red granite masses are, in general, only dyked by veins of diabase.

6. The whole of these igneous, volcanic and metamorphic rocks, (with exceptions noted in the text) have been planed down by marine erosion, the Nubian Sandstone being laid down on the smoothed surfaces.

7. The Nubian Sandstone is, at any rate in part, Upper Cretaceous (Santonian) in age, there being no proof of beds older than that period in this district.

8. Cretaceous Limestones overlie the sandstone, and are mainly Middle Senonian (Campanian). They belong to three facies, (1) the Duwi type, with *Ostrea Villei* and *Trigonoarca multidentata*, which reappears further south on the Nile; (2) the Hammama type, characterized by a rich cephalopod fauna, especially *Ptychoceras*, and (3) the Mellaha type, characterized by *Gryphæa vesicularis* and *Plicatula spinosa*. A fourth, the deep-water series of Wadi 'Araba, commencing with the Cenomanian, is not here represented. The character and variability of the beds points to their being of shallow-water origin, and phosphatic layers are especially noticeable.

9. There is a marked unconformity between these strata and the overlying Eocene limestones and shales.

10. The Eocene consists of two divisions, the Serrai limestones and Esna shales, probably Londinian and Suessonian in age. A characteristic feature is the lithological similarity of these beds throughout the whole district, suggesting uniform depression, though the appearance of oyster beds, and nodular limestones do not point to great depths having been attained.

11. Andesites have been intruded into these Eocene limestones in Abu Had, the latter having undergone contact metamorphism in consequence.

12. The Oligocene is not represented.

13. The Miocene is only represented in the north-east part of the district, and its fauna has no Red Sea elements in it.

14. A series of sandy limestones in Wadi Qena appear to be directly due to marine or lacustrine conditions following the main faulting, and may provisionally be classed as late Pliocene.

15. The Red Sea as such probably first came into existence in late Pliocene times, the highest coral reefs (now over 200 metres above sea-level), containing a possible intermixture of Pliocene and Pleistocene corals. From here, too, probably dates the origin of the chief Red Sea ranges.

16. The youngest coral reefs are associated with gravels and conglomerates which must themselves be of Pleistocene age.

17. The igneous gravels and conglomerates of Wadi Qena unconformably overlying the sandy limestones are also, in part, at least of the same date.

E. Fraas* has contributed an important addition to the knowledge of the igneous rocks displayed on the Qena-Qosseir road. Thus

* *Loc. cit.*

he has clearly recognized the presence of gneiss in the Mehetih (our Meeteq) range, and the importance of both grauwackés and ancient schistose rocks. On one point especially he has a note which should be kept in mind by future observers, viz., that the gneiss is inserted between the quartz-schists and hornblende-schists in Jebel Fanana, whereas in the sections examined by the writers the former underlies all other members of the metamorphic series. On the other hand* he distinctly recognizes the gneiss as the oldest member, and regards it as occupying its above position owing to a flat doubled overthrust. Thus his views on this point agree with those expressed in this memoir, while comparisons will show many interesting points where the two sets of observations illustrate each other.

W. F. H. & T. B.

SECTION X.—PRACTICAL NOTES.

While reserving a fuller description of the rocks and ores which may be of practical value till analyses, etc., have been carried out, reference may be made here to the districts which are most likely to be profitably developed. Undoubtedly the principal of these is the country lying between the western border of the area south of Wadi Gareya and the Jidami-Jarra and Wadi 'Esh ranges, which would present no great difficulties to the development of a light railway. The question of water-supply is more serious, but in the mountains water is not entirely absent. The well in the gorge in Wadi Jidami is stated to be an inexhaustible spring, and only requires reopening, having been closed owing to a tribal dispute. Our guides said that when in use, a hundred camels could be watered there at one time. A second well, probably rather poor, exists in the direction of Jebel 'Aradia, but was not visited by the writers, while water is plentiful in fissures near the head of Wadi 'Esh. This supply would scarcely be sufficient, and the question therefore arises whether borings would be likely to be successful.

Wells, pools and water supply.

The facts are not altogether unfavorable to the possibility of water being thus obtained by borings made in the Nubian Sandstone area, where the vegetation in parts of Wadi Hammana is much more luxuriant, and fresher in appearance than in other of the desert wadis. Only a little further to the south, on the southern Qosseir road, where the geological conditions are similar, water is found in fair quantity

* *Loc. cit.* page 38.

at the village of El Geita, where shallow wells have been sunk in the calcareous sands and marls of the Nubian series, these being thirty in number, while still further to the east, in the Wadi Rod'aid, there seems to be possibility of water being found not far from the surface. On this road, passing through the igneous and metamorphic range, there are the wells of Hammamat and El Sidd, both of which have been sunk in the wadi, probably in the above rocks, as the Hammamat well is very deep. At El Sidd, on the other hand, the water is practically at the level of the ground.

Continuing along the Qena-Qosseir road there is another well in Wadi Seyala, called Bir Seyala, and further north is Bir el Beida or Bir Inglizi. All these wells are, with the exception of Bir el Sidd, slightly brackish, although quite drinkable. Nine kilometres to the north-west of this road, in the limestone valley of Nakheil, is Bir Nakheil, containing a slightly brackish but drinkable water.

On the coast-plain to the north of Qosseir, water is rarely met with except in the hills. In Wadi Queh in the plain, there is a well which only contains water after a rainstorm, and dries up soon afterwards; also in Wadi Safaja there is another which is so brackish that it can only be drunk with impunity by those accustomed to it.

Following up Wadi Safaja on the road which leads to the Nile Valley, there is Bir Abu Diab, a pool of good rain-water in Jebel Safaja or Abu Diab, which is quite near to the south side of the wadi, and about a day's march from the previous well. Rain-pools also occur in Wadi Wasif, about four hours' journey from the road. Higher up the wadi, where it is joined by Wadi Abu Marwat, rain-water pools occur, but they were dried up when visited in the end of December, 1897.

On the other side of the water-shed in Wadi Markh, rain-pools are found in Jebel Missikat el Qukh; while to the north of Wadi Fatiri a good supply of rain-water is found in Jebel Um 'Anab. Eastward from this point to the south of Wadi Um Tagher and about two hours journey from the hill of that name, there is a brackish pool drinkable only by camels.

In nearly all the granite ranges pools of good water are found. Such an one is Bir Um Dalfa, which occurs at the foot of Jebel Um Dalfa (see description in the topographical part p. 72) and also that at Minfeih.

At the foot of the escarpment of Abu Sha'ar, on the seaward side, is a brackish spring which, according to Mitchell, contains sulphuretted hydrogen.

On the Qena-Jebel Zeit road, when traversed in the end of December, 1896, the following notes on the wells were made:—

*Bir Arras,** at the foot of Jebel Arras, is a hole in the debris of the wadi close to a gravel cliff, with only a small quantity of brackish water at the bottom, easily emptied, and collecting again slowly. It is half a day's march from Qena and 3½ days from the next, viz.,

*Bir Um Disi.**—This is a large pot-hole of polished granite in the wadi of the same name, filled with rain-water. There are one or two others higher up the valley and connected with each other. It lies 2 or 3 kilometres to the east of the road.

*Bir Gattar,** a rain-pool in the granite rock in Wadi Gattar, is about 4 hours' march from the previous well, and lies 2 kilometres east of the road, on the south-east side of the wadi. The Bedawin say there are two wells close together.

Bir Dokhan * *or Beidia* is a fairly good well but slightly brackish, dug out of the detritus in the valley near the mountain-range of that name, and lies about 6 hours march north of Bir Gattar.

Bir Mellaha * is a brackish spring situated in the plain about half-way between Jebel 'Esh range and that of Mellaha. It is too brackish for human use, and camels, unless very thirsty, refuse to drink it. There are a few palms and tarfa bushes near by.

To the north-west of Jebel Zeit and about one and a quarter day's march from the previous well, is Bir Abu Nakhla, a shallow pool of brackish water in the gypsum and marls of the plain. Several roads converge on this well, and numerous caravans pass here evidently on their way to the large saline which occurs in the plain to the north.

Bir Mongul and *Bir Dara* occur in the two mountain-masses bearing these names on the opposite sides of Wadi Mongul. When visited in April, 1898, the former was dried up and the latter only contained a very small quantity of good water.

Although not occurring in this area the wells of Gharib may be mentioned. The first, which is called Bir Gharib by Mitchell, occurs in a small gully on the south-east side of the mountain and quite close to the plain. This writer states that "it furnishes an unfailing supply of the purest water to the flocks of sheep and caravans of camels belonging to the Bedawin tribes living, or coming within its reach," but when visited in April, 1898, it was practically dry, and it was only after clearing out the sand and mud and leaving it to collect for a night that a meagre supply of water was obtained. On the western

* See analysis in Appendix and Plate I.

neighbourhood of that river. Barron first called attention to their occurrence south of Esna, but the chemical results were not very satisfactory, later however during the same expedition he re-discovered them at Jebel el Qurn, only 10 kilometres from Qift, in a plateau which was 1 to 2 kilometres in greatest width, and had a length of 9 to 10 kilometres. In the report above-mentioned, it is pointed out that the phosphate-bed sometimes forms the surface of the plateau, when it is in the form of rubble; while in most instances it is covered by rubbish attaining a maximum thickness of 3 metres. The thickness of the normal bed is nearly one metre, but the upper part has already undergone silicification, though this does not appear to have affected the sample very injuriously. Other bone-beds were also noticed, but are of less importance.

The analysis of a type-specimen yielded 22·5% of P_2O_5 (phosphoric anhydride) equal to 49·11% of $Ca_3P_2O_8$.* In the autumn of the same year, during the return from an expedition made by the writers to the old mines of 'Aradia, an examination of the rock exposed in the gullies and slopes on the eastern edge of the low plateau running parallel to a ridge connecting the limestone ranges of Serrai and Abu Had led to the re-discovery of the phosphate-bed, and the simultaneous finding of undoubted Cretaceous fossils in the overlying limestone, a key being thus provided which has enabled them to show that the phosphatic beds are in every instance intimately associated with strata of that age.

These beds are a little over 20 kilometres to the W.N.W. of Qena,† and are easily reached by the ordinary camel-road running from the latter town up Wadi Qena through Wadi Gareya into the Hammama plain, which is bounded by the Cretaceous plateau. The proved area of Cretaceous beds mapped by Green in this region has a length of 25 kilometres, and an average breadth of a kilometre, the phosphatic beds being of common occurrence within this space. To the south the overburden is a hard limestone about 2 metres thick, but further north they are practically almost at the surface; the bones being of large size and very brittle owing to the absence of this hard covering layer, these low plateaux at the foot of Abu Had may be more easily worked than the others.

The stratum itself is strictly a bone-bed, partly siliceous, which on fracturing shews a number of oval or rounded white fragments (coprolites) as well as abundant sharks' teeth and vertebræ, while its general thickness may be taken as from 0·6 to 1 metre, in most cases

* For the analyses of further specimens see Appendix II.

† The Phosphate Deposits of Egypt, Cairo, 1900.

not perfectly continuous, but separated into two portions by a layer of siliceous limestone poor in phosphatic contents. The results already obtained lead to the conclusion that the Egyptian variety is, on the whole, somewhat inferior to the phosphate of South Carolina (57-63%), but probably in general superior to that from Belgium (45·3%). Though the deposits near the Nile are, commercially, the most important, the phosphatic bands are by no means limited to this neighbourhood, but it may be stated in general terms that the phosphate beds form a part of the Cretaceous series wherever examined in the district, with the possible exception of the Jebel Mellaha region. Thus, in the above-mentioned report, descriptions of their occurrence are given in the Duwi range, and at the confluence of Wadi Wasif and Wadi Safaja, both of which are not far removed from the Red Sea coast. It also contains wider suggestions as to the possible distribution of these beds to the southward.

Summary.—Phosphatic beds are present in connection with the Cretaceous strata wherever the latter have been examined in the Eastern Desert between latitude 27° N. and latitude 28° N. Agricultural experiments, an examination of the cost of transport, and further analyses are required to show whether these deposits are a valuable asset of the country.

Sandstone.—The plateau lying to the west of Jebel Jidami is composed of the Nubian Sandstone, which, as is well-known from the good preservation of the Egyptian monuments made of it, and of the inscriptions carved thereon, is a rock of a durable character in this country. Though not in itself capable of competing with the same rock obtained higher up the Nile, on the bank of the river, it would become a useful by-product if the country were developed for other purposes.

Hæmatite.—Wadi Abu Jerida, a small valley running to the east **Iron ores.** from Wadi Hammama, has been the scene of great mining activity in former times. Close to its entrance, traces of one or two buildings and old forges were met with, while, round pits now filled with sand, pieces of good hæmatite ore were still lying. A closer examination of the neighbourhood showed that the ore was by no means exhausted, heavy ore cropping out at the surface at the western end of the wadi, while an analysis of this mineral made by Lucas shows that the samples brought back contain 67·20% of ferric oxide, representing 47·04% of metallic iron, the impurity being mainly silica. This

percentage is less by 4% Fe_2O_3 than that of the ore now being worked at Ulverstone in England. It appears probable that the hæmatite at this point is due to segregation of the iron ore from the dolerite itself, and if the commercial and other conditions were favourable for the production of iron this spot might repay closer examination. Further east, the hæmatite, which is of a micaceous nature with brilliant metallic lustre, appears to be connected with quartz-veins only, the sides of some of these being still rich in this ore. These veins have been much worked, but some carrying small quantities of ore at the surface are still untouched. An analysis of the micaceous ore gave no less than 82·4% of Fe_2O_3, representing 57·68% of metallic iron. The whole of the conditions observed suggest the possibility of there being large masses of hæmatite below the surface, portions of which have been carried up by the veins of quartz, which consisting as they do of crystals loosely grown together, point to their having been formed from heated solutions.

Iron ores of Jebel Abu Marwat.

Iron Ores.—These ores in the forms of limonite, chalybite, and yellow ochre (the latter in small quantity only) are extensively developed in the ranges bounding Wadi Abu Marwat on the east, one of the torrent-beds draining into this wadi being filled with large blocks of banded siliceous limonite derived from contorted veins near the summit of the range. Huge veins of a poor chalybite and the better class limonite are also present in the foot-hills. But in spite of the great quantity of the ore, its out-of-the-way position and probable low percentage of iron, will place it at a disadvantage when compared with the richer hæmatite of Abu Jerida.

The ores here seem to be close connected with the dykes, and become richer where the latter have been subject to considerable stresses. In a sharply conical hill (see Topography, p. 59,) the bands have been first thrown into V-shaped folds, which have then been rent asunder, and it is in the neighbourhood of these fractured portions that the ore appeared richest.

Iron ores of Wadi Dib.

Good iron ores are also present, as previously stated, in the upper regions of Wadi Dib, where most of the dykes, penetrating the granite to the south of the El Urf chain, consist of poor chalybite, or are quartz-veins rich in hæmatite. In one hill to the north of the valley, mere surface digging had brought to light a brilliant micaceous variety, which seemed to be extremely abundant throughout the whole of agranite hill. The analyses show the ore of this district to be of good quality, the percentage of surface samples being 77·99% and 75·94% of Fe_2O_3

respectively, a very good result considering that the specimens were taken practically from the surface.

Copper.—The same region, or more strictly speaking, the granitic belt bounding the metamorphic hills north of Dara, may repay further examination, as veins of the blue silicate of copper, *chrysocolla*, are met with from time to time. These latter are especially developed in the sides of some old workings occurring in the dark range of Jebel Dara, where a syenitic dyke cut into for a good distance was lined with the blue mineral, but no trace of the copper ore could be found. An old Arab also showed pieces of copper pyrites as coming from the same district, but owing to the season being at an end, it was impossible to follow up the clue. **Copper.**

No lead ores have been recorded by the Survey expeditions in this desert, but C. J. Alford, in a recent report* has called attention to some ancient workings in a steep hill of crystalline limestone about two miles south of Safaja Bay. The main points of interest are thus described: "The strata of limestone are sharply tilted up from the east and the adjacent country generally disturbed. The whole side of this hill is covered with old workings which appear to have penetrated to a bed of indurated limestone, which occurs a few feet below the surface, and which carries impregnations of galena. Almost every trace of this ore has been removed by the old workers, so it is difficult now to ascertain what this bed ever contained. A sample of galena was, however, collected by chipping small pieces from the limestone wherever any of the ore could be seen, and this, roughly concentrated, gave on assay, lead, 50 per cent, gold, 2 dwts, and silver, 3 ozs. per ton." It is presumably this discovery that led to the rumour current in Cairo as to the existence of important silver veins 2 metres thick near the Red Sea. **Lead Ores.**

Gold.—While the specimens submitted by the Survey for analysis have not yielded any trace of the precious metal, C. J. Alford has recently published a report † under the auspices of the Egyptian Mines Exploration Co., which has obtained a concession of a large portion of the southern half of the district considered in this memoir. His results are more favourable, though less satisfactory than might be wished for in a district so devoid of water and communications.

* "Ancient and Prospective Gold Mining in Egypt, March 1900."
† *Loc. cit.*

The followed are the principal localities examined by Alford, with the average yield per ton:—

	Gold.		Silver.	
	Dwt.	Grs.	Dwt.	Grs.
Wadi Hammama, south side of west end, quartz-veins with hæmatite..	1	12	3	—
(This locality is probably Wadi Abu Jerida in which our own samples were examined for gold, but none was obtained).				
Wadi Hammama, east end..	2	0	3	—
'Aradia, old workings, east vein..	1	12	3	—
" " "	3	12	6	12
" western vein	3	—	2	—
" old working, north vein..	11	12	2	12
" " "	1	12	2	0
Wadi Safaja...	6	12	3	—
(This locality, which is 26 miles from the pass at the head of Wadi Safaja on the N.E. side, yielded the maximum in white crystalline quartz).				
Jebel Jasus. Galena. Lead 50%	2	0	2	12
Um 'Esh..	11	12	—	—

The gold in Jebel Jasus appears to have been obtained from a sample of galena occurring in indurated limestone at that locality, and the presence of that mineral is of much interest, though judging from the report it seems that only a small sample could be collected.

At first sight the above-mentioned analyses do not encourage much hope of the formation of a stable gold industry in these desert regions, but as the matter is now being tested by experts on the spot, the research must be considered *sub judice*, and it can only be hoped that Alford's first results may be the precursors of better things.*

Old Mines.—The characters of the various mining areas have already been referred to, but they may be more closely considered in connection with the report above-mentioned. Thus the district described under the heading "*Wady Hammama*" is the *Wadi Abu Jerida* of the Survey, and the vein of white crystalline quartz from 12 to 30 inches in width with much specular iron, a sample from which showed on assay 1 dwt. 12 grs. of gold per ton of quartz, is probably the same as the one which yielded the hæmatite (specular iron) with 82% Fe_2O_3. As the veins here have never yielded more than 2 dwts. of gold per

* Newspaper statements have been made according to which 10 oz. of gold per ton have been obtained in a reef at Um Roos, a little to the south of this district, while the average of 30 examples was 1 oz. per ton.

ton (the Survey analyses showing no traces of gold, although especially tested for that metal), this region does not appear promising except for the iron ore. Some good jasper is also present in the valley, but only small blocks can be obtained, owing to the rock being much jointed.

'Aradia.—These are the Jidami Mines, and the veins, especially on the eastern side, have been much worked out. Here again the results have been very unpromising, the maximum obtained in a large old stope, at a depth of 30 feet from the surface being 3 dwts. 12 grs. The writers' results were even less favourable.

Fatira.—The old workings mentioned as being present in the Hadrabia hill-system have also been re-examined by Alford; here due north of the main ruins, and apparently lying wholly in the granite are small veins of crystalline quartz, one of which yielded on assay 11 dwts. 12 grs. of gold, but another result about half a mile to the north-east gave only 1 dwt. 12 grs.

Um 'Esh.—These important workings were thus briefly described in the original field report sent in by the Survey. "On the south of Wadi 'Esh the metamorphic rocks are full of old workings, which have evidently had as their object the exploitation of the quartz-veins running through them. Gold naturally suggests itself as having been the object of the seekers, but of this metal no definite or satisfactory trace has been found. Some of the veins are composed of carbonate of iron, which does not appear to have been worked." The vein mentioned by Alford is a different one, as it lies in a vein of quartz running through granite, but is evidently close to those above-mentioned. It assayed 11 dwts. 12 grs., of gold per ton. Attention may therefore be called here to the metamorphic area adjoining the granite, and especially to the very fine quartz reef lying between Wadi Um 'Esh and the El Rebshi range.

Fowakhir.—These mines are practically outside the district, and yielded no gold results when examined by Prof. E. Fraas and the Survey expedition. Alford has had a little more success, as he reports from 2 to 5 dwts. of gold per ton of rock. The average of the seventeen essays made by him in the district covered by this memoir is a little over 4 dwts. of gold per ton of rock, a record which will have to be considerably improved if the work is to prove profitable. The average for the mines south of the district (excluding Fowakhir) is a little over 6 dwt. per ton. He gives it as his opinion, that taking all the circumstances into consideration, the prospects of finding payable gold mines

are sufficient to justify the employment of capital in an exhaustive exploration, is and so long as the shares are held by capitalists only, such an investigation must be welcomed as throwing further light on an interesting district.

Coal.

Less satisfactory is the statement that the company propose spending £5000 on making test bore-holes at Rhedesia, near Edfu, with a view to finding whether coal be or be not present at that locality. Such an expenditure seems in no way justified by the geological facts noted by the Survey, seeing that the very beds which it is proposed to explore come to the surface east of Qena, the carbonaceous shales being immediately succeeded by sandstones and marls of the Nubian series.

Building stones.

If the precious metals have not yet been found in any large quantity, the Red Sea Hills have long been famous as the only home of some very rare and beautiful rocks, which are to be found forming part of some of the finest monuments of Roman and Byzantine times. Most notable amongst these is the Imperial Porphyry.

Imperial Porphyry.

Imperial Porphyry, was very actively worked during the reigns of Trajan, Hadrian, Nero, etc. The quarries of this rock are still in as perfect condition as when left by those who started them, but it is questionable whether under present conditions they would be worth reopening, though the Red Sea is within comparatively easy reach. The principal locality is in a basin-like valley surrounded by the high summits of the Dokhan range, a steep road, still in fairly good preservation, leading from the ruined temple up one of the western slopes. The quarry itself is nearly at the summit of the hill, the purple porphyry forming vertical walls (due to quarrying) some 25 metres high, and being in intimate connection with the dark andesite with small white crystals (itself a fine-looking rock), and a brick-red felsite. There are other occurrences of the porphyry in Jebel 'Esh and El Urf.

W. Brindley* after giving an account of his visit to these mines states,† in a note "These porphyry quarries, after having been lost sight of for 1500 years, and having lain dormant for probably 1700 years, are once again to be worked. The Romans carried their blocks to the Nile —a distance of ninety-six miles—; but now that there is a direct route through the Suez Canal, they will be taken to the ancient port of Myos Hormos, on the Red Sea. This route being a gentle incline, and the distance a little more than twenty miles, cheap sea transit from this

* Trans. Roy. Inst. Brit. Architects, April, 1888.

† *Loc. cit.*, p. 22.

port will now enable this valuable material to be obtained in Europe and America, in large sizes, at a reasonable price; and, by improved machinery, the cost of working will be reduced nearly to that of granite." This sanguine forecast has not been fulfilled up to the present time, probably owing to the difficulties of transport and water-supply, as the quarries were not being worked when visited in 1898. At the same time, the rock is present in large quantity, and only requires favourable economic conditions to again take rank among the leading ornamental stones of the world. Both Brindley and Schneider give beautiful photographic reproductions of monuments in which this stone has been especially employed, and the great cathedrals of Italy contain a fine series of examples, such also having been noted by Hume in the Duomo and Museum at Naples, in Venice, and at Constantinople, while Schneider has brought together the most detailed information as to its occurrence and use.

Breccia Verde Antico.—Not less distinctive is a remarkable brecciated conglomerate, consisting of fragments of rocks of the most varied description cemented in a hard paste, which is variable in colour, though, as the name indicates, green is predominant. The best-known locality for this rock is in Wadi Hammamat, on the Qena-Qosseir road, where it was worked even in early Egyptian time, but it is by no means limited to this neighbourhood, having been noted at the mouth of Wadi Dib, and being also splendidly developed in the region to the west of Jebels Dara and Mongul in the El Urf chain. Indeed the whole of this district is of special interest, traces of copper (as veins of silicate), a porphyry near the imperial variety, a grey marble, and hæmatite being close to one another. The Breccia Verde has also been found in Eastern Sinai, in one case crowning the summit of the Ferani range at over 1500 metres above sea-level, being further evidence of the close connection existing between the mountain ranges now separated by the Suez depression.

Dolerite.

Dolerite.—The above does not exhaust the basic rocks or members of the volcanic series which have been used for ornamental purposes, the dolerite in the neighbourhood of Wadi 'Esh (near Qosseir) being extremely hard and compact, and apparently identical with one which has been used by the Ancient Egyptians for statues and ornamental bowls, while the perfect preservation of a cartouche of Rameses III. in Wadi Atolla, further testifies to its durability. This stone, which is almost black, would be useful for all purposes where a rock of extreme hardness is required, and is present on a large scale near the locality

above-mentioned, but the lack of jointing would also make it somewhat difficult to work.

Slates. *Compact rocks allied to the slates and talc-schists.*—Archaeologists have been long acquainted with a compact grey rock which has been largely used for ornamental purposes, especially as plaques on which figures of leopards and other designs have been cut in low relief. This type of stone has now been shown to be very widely developed in the low hill-region to the west of Qosseir, typical exposures having been noted bounding the plain of Wadi Saga west of the Duwi range, and at many other points. It is interesting to note that this particular variety does not extend far north of the main roads connecting Qena and Qosseir.

Gabbros, diorites and granites. In addition to the above stones, there are lighter varieties which owe their beauty and value to the close intergrowth of the darker and lighter constituents, the black hornblendes, mica, etc., disseminated in a dead-white paste of felspar giving rise to an artistic black and white mosaic. The best-known locality for this rock is the well-known Roman station of Mons Claudianus, which has been previously described by Wilkinson,* by Lefèbvre,† who visited it in 1837, Floyer,‡ and Schweinfurth.§ The two latter have dealt with the subject in so complete a manner that it is unnecessary to re-describe it in this memoir. In Schweinfurth's opinion, the rock was simply worked from motives of state, viz., to keep the numerous prisoners in employment, but the rock itself is specially suitable for columns and statuary work, and if nearer the Nile the quarries would be well worth reopening, though at present their isolated position would probably prevent their being worked at a profit. Thus they are 110 kilometres from Qena, though the road is easy, while to Myos Hormos (Abu Sha'ar) is 55 kilometres, with some difficult points near the watershed itself. Schweinfurth has also shown the position of one of these pillars on his map, this being no less than 18 metres long by 2·6 metres broad, while a number of others have been left at the corner of a small valley, his "Saulenthal." Similarly, a large sarcophagus lies on one of the western slopes, close to the quarry from which it was derived. The chief defect of the rock itself is its lack of hardness, which, while rendering it easy to work, makes it much less durable than is desirable in monumental work, though it would probably

* *Journ. Roy. Geog. Soc.*, 1832.
† *Bull. Soc. Géol. France*, Vol. X.
‡ *Journ. Roy. Geogr. Soc.*, Nov. 1887.
§ *Zeitschr.* d. *Gesellsch.* f. Erdk. zu Berlin, 1897, Bd. XXXII., p. 22.

stand well in a climate like that of Egypt. It is, however, to be feared that Mons Claudianus will for many years remain buried in the silence from which it briefly emerged during the Roman period.

Diorite of Wadi Semna.—In the small wadi opening opposite the Semna Lokala on the eastern side, a coarse-grained gabbro of similar general appearance has been worked by the Romans, and inscriptions carved on a block of the stone were still in good preservation. The quarries to-day are just as they were left by the old workers, and could under favourable circumstances be immediately available for exploitation. It is probably of a more durable character than that of Mons Claudianus, but is as badly placed as the latter for transport. Speaking generally, these speckled diorites do not appear to occur north of lat. 27° N., but are largely developed in the hills north of the Qena-Qosseir roads. A very beautiful bowl made of this material was found at Naqada by the members of the Egyptian Exploration Fund.

Granites.—Granite, it need scarcely be said, exists in the greatest abundance and variety throughout the whole district, but has not been worked at any point except at the mouth of Wadi Foakhir. Owing to its easy surface-disintegration, good type-blocks are very difficult to obtain, but with a large supply obtainable on the river itself at Assuan, it is not probable that these rocks would be in any demand for some time to come.

Red and grey gneiss.

Red Gneiss.—Special attention may also be called to the development of a beautiful red gneiss present in large quantity in the upper part of Wadi Sodmein forming the lower slopes of the Meeteq range, a grey variety being in close association with it. This rock is within easy reach of Qosseir, and seems very suitable for ornamental purposes, while it is also developed on the Hammamat-Qosseir portion of the Qena-Qosseir road.

Quartz-Felsite.—Though many dykes would yield stone of an ornamental nature, and quartz-felsite especially is abundant throughout the district, it is particularly well-developed in the narrow gorge at the entrance to the Jebel Jidami range. From its massive character, and capability of taking a polish, it is a good ornamental stone, though the lack of jointing would render the quarrying somewhat difficult.

Black serpentine.

Amongst other occurrences of interest, but of local development only, may be mentioned a black serpentine, which is much valued by the Ababda, who make pipes of it. A very black rock in Wadi Sodmein, near the foot of Meeteq, appears to be of this nature, while green varieties are also met with in Wadi Um Disi and at the foot of El Rebshi. It was used by the Egyptians for scarabs.

Jasper.

Red jasper of good quality, but unfortunately in small quantity, is found in a dyke in Wadi Abu Jerida, and also at the head of this valley in the latter place being associated with chalcedony and agate. Its value is also diminished owing to its brittle character, rendering it difficult to obtain large specimens.

Marble.—Near the head of Wadi Dib there is an interesting occurrence of a saccharine grey marble, which, though not comparable with the white Italian varieties, would nevertheless be much sought after, if it were in an inhabited district, as it is very uniform in texture and tint, and is at the same time several metres in thickness, being closely associated with a well-marked band of schists and gneisses, apparently running parallel to the El Urf range.

Of less important products in the southern half of the district the following may be mentioned. The limestone in Jebel el Jir is being worked in places for lime, while at the foot of the Serrai range, salt is in sufficient quantity to supply the needs of the Arabs, but is not smuggled by them for sale. The Eocene shales near the river contain small quantities of nitrate, and are used by the natives for spreading over their fields. A few Arabs, too, gain a precarious living by charcoal-burning in the more fertile wadis round Fatiri, but in general the district is very sparsely populated, almost the whole of the communications from Qosseir to Qena going by the southern road.

In the northern half of the district the hills have in the past yielded mineral wealth which has been the source of great activity, especially during Roman times. The most important of these is—

Petroleum.—The petroleum of Jebel Zeit has been the subject of many researches, and is at the present moment being re-investigated by a company. The surface indications are not very satisfactory, a layer of petroleum swimming on the surface of a pool in two holes which have been opened on the eastern side of the hills near the sea. It appears to owe its origin to the decomposition of the organisms contained in the coral-reef, as suggested by Fraas. As this oil will form the subject of a special detailed report, no further reference will be made to it here.

Gypsum and anhydrite.—While gypsum is a great source of industry on the Nile, the vast and practically inexhaustible supply at Jebel Zeit is untouched, probably because it would not pay to quarry it and carry it by sea to Suez. Otherwise the product seems a very pure one, and the hills surrounding the central igneous core are entirely composed of it.

In the mass of gypsum in the range of Jebel Zeit there occurs a bed of anhydrite nearly 8 metres thick, apparently almost pure, while beds of crystalline gypsum also occur along with it.

Sulphur.—This has been practically worked out where it exists in Ras Jemsa. Like the petroleum, it has been formed by the decomposition of the organic matter in the rocks, and the stages of this change are observable in the coral-reef bordering the petroleum well.

The following notes give a summary of the principal rocks and minerals of possible commercial value met with in the neighbourhood of the principal routes or in definite districts:—

Qena-El Geita-Qosseir (southern road):—Phosphates (near Qift), sandstone, breccia quarries (*pietra antico verdi*), gold.*

Qena-Qosseir (northern road):—Phosphates, sandstone, hæmatite of Abu Jerida, dolerite, jasper, gold*, red gneiss.

Qena to Jidami:—Phosphates, sandstone, gold,* quartz-felsite for ornamental purposes.

Qosseir to Mons Claudianus:—Phosphates, jasper, iron ores and ochre, diorite of Semna and Mons Claudianus.

Qena to Mons Claudianus:—Phosphates, gold* in Hadrabia.

Qena to Jebel Zeit:—Imperial porphyry, sulphur, gypsum, anhydrite, petroleum.

District between Wadi Dib and Gharib:—Hæmatite, marble, possibly copper ores, ornamental breccias, etc. W.F.H. & T.B.

SECTION XI.—THE PETROLEUM OF JEBEL ZEIT,† ETC.

The occurrence of petroleum, etc., at this part of the Gulf of Suez has been known since ancient times.

In 1865 a concession was granted to work the sulphur at Ras Jemsa, and the extraction was carried on for a few years.

In 1884 a Belgian, M. de Bay, called attention to the occurrence of petroleum in old workings at Ras Jemsa and Jebel Zeit, and the Egyptian Government arranged with him to purchase boring apparatus and engaged borers in Europe in order to ascertain whether oil existed at Jemsa in paying quantities.

* This is recorded on the strength of the report issued by the Egyptian Exploration Company. Were their efforts to be crowned with success, there would be no geological reason why this mineral should not occur both in Eastern Sinai, and the Sudan. Nearly all the old mines occur near the junction of the metamorphic rocks and granites, similar country being present in all the above-mentioned districts, often accompanied by quartz-reefs of a striking character, but the Survey analyses show that as regard the surface, gold has practically not been detected.

†See Plate VII and V.

A report on the subject, dated May, 1885, says:—"Ras Jemsa, Jebel Zeit and Jafatin Island were successively visited".

"At the north end of the east coast of Ras Jemsa were two horizontal galleries which had been formerly driven, and in which were numerous vertical shafts, one having a depth of at least 25 metres was filled with petroleum."*

At Jebel Zeit the surface holes are described as filled with oil, but this again was probably petroleum floating on water. A cutting 150 metres long had been made in the beds of the raised beach, and at the far end a shaft had been sunk for more than 25 metres.

On the arrival of the working parties, petroleum was noted as standing in the holes in the galleries, 0·02 to 0·04 metres on the top of salt water (as surmised.)

First, the old well-holes were joined by a trench which cut through blue clay 0·50 metres thick at the east end of the gallery, and another 0·60 metres thick at the west end. De Bay assumed that the petroleum was below this bed and rose up through it by pressure. His theory was that there was a "canal sous-marin de petrole" between Jemsa and Jebel Zeit.

Six wells were bored by De Bay round the hill-mass on the east side of Jemsa near the old wells. No. 1 well was bored to a depth of 28·9 metres and was said to have yielded petroleum freely, No. 2 yielded only a little, while No. 3, which was bored some distance away from the others, yielded none at all.

The strata passed through in all these borings were those which have been called Beach Deposits by the Geological Survey, and are undoubtedly of Newer Tertiary age. Older rocks were evidently not touched.

These wells not proving a success were closed up and abandoned.

Early in the following year (1886), M. de Bay crossed over to Jebel Zeit and opened two new wells about 50 metres apart, one being 15, and the other 40 metres from the sea-shore. In one of these, at a depth of 34·50 metres, a considerable quantity of gas was disengaged, and at 35·30 metres, petroleum rose to 1·80 metres above sea-level, and yielded about 60 litres per hour. On boring down to 40·78 metres, by the aid of pumps 300 cubic metres were got out per diem, of which a quarter was petroleum. This oil contained 22% lighting oil, 13% heavy oil, and 8 % lubricating oil.

Owing to the want of storeage room for oil at this time, the tube was forced down to cover the fissure supplying the oil; but there seems

* It was probably petroleum floating on water, since the galleries are only 1 to 1·30 metres above sea-level.

to be a doubt about this, as in a report by a Mr. Jones from England, who was examining the ground with a view of undertaking the exploitation of a part of this region, it is stated that the supply is in all probability exhausted in this particular bore.

After M. de Bay's departure, arrangements were made for working this district with vigour, and American, Russian, and Roumanian workmen were engaged to prosecute the work. Five wells were drilled by these people, one of which was carried down to 636 metres, but of this there does not seem to be any very authentic record, no specimens of the rocks passed through having been preserved, nor is there any statement as to its position, except that it was made at Jemsa. As far as can be seen, these bores did not yield oil in very large quantities, and eventually were abandoned.

Mitchell, in 1887, and Col. C. E. Stewart, in 1888, both examined the district and were of opinion that oil was to be found there, the latter indicating several places where bores should be put down.

From this time to 1896, when the Geological Survey was formed, nothing more was done in the matter. In the latter part of November of that year, a demand having been made by the Finance Ministry for a report on the district of Jebel Zeit and Jemsa, the Director (Capt. Lyons) and one of the geologists went down by Coastguard steamer from Suez to make an examination and map this district. On arriving at the place it was found that, in order to make a proper map, it would take more time than could be spared then, so three traverses were made to determine the structure of the country and the probabilities in favour of petroleum being found in paying quantities. As a result of this traverse, it was found that Mitchell's map did not represent the true structure of the country, and consequently his deductions concerning the petroleum were erroneous. After completing the traverses and comparing notes, a conclusion unfavourable to the presence of petroleum in paying quantities was arrived at, on the following data:—the presence of much faulting along the sea-coast, thus cutting off communication with the strata beneath the sea; and the fact that the igneous rocks in Jebel Zeit acted as a barrier on the west to any connection existing between the beds on its western slope and those on the seaward side. The fact that petroleum had only actually been found on or near the sea-coast, and had never been recorded from the plain to the west of Jebel Zeit also lent weight to the adverse conclusion.

During the spring of 1898 this district was again visited by two survey parties in the course of their work from Qosseir to Gharib Lighthouse, and the result of their examination was entirely in agreement with the report made in the previous year.

The following is the report on this district and on the opposite shore of Sinai:—

Jebel Zeit Petroleum.—The district where the bores were put down in the previous search for oil lies close to the sea-coast, being situated on the coast plain, bounded on the West by the range of Jebel Zeit. This plain, at the old buildings near the petroleum wells, is between three and four kilometres wide; but opposite the wells it is only three quarters of a kilometre. Opposite the buildings is an area of salt-bearing clay which becomes soft during the night owing to the absorption of moisture from the sea-air. Here patches of the Pleistocene occur, especially at the foot of the Zeit range, forming a low terrace.

Opposite the wells, and between them and the houses, the Beach Deposits and the coral rock filled with recent shells form a low plateau, which gradually approaches the sea until at half a kilometre to the north of the wells, it forms a low cliff on the shore. From this point it continues northwards till it is cut out by the granite and Nubian Sandstone of the hill range which run right into the sea.

Wells. The wells occur close to the sea-shore in the Raised Beach. One is simply a pool in the gravel and clay of this deposit; while the other occurs at the end of a cutting through coral rock. In both of these, was a certain amount of petroleum and bituminous matter floating on the water collected there, but there did not seem to be any oil rising at all. On the contrary, it seemed to collect from the above-mentioned coral limestone, as it was seen to be in numerous cracks and fissures in the rock, and the surface had a dirty, oily appearance from the oil which had oozed out and trickled down.

A little distance to the north of the wells there is a place at which a strong smell of petroleum comes from the sea as it washes against the beach limestone. This, of course, indicates the presence of a source of oil probably a little distance under the water. As the beds of the Beach Deposit lie almost horizontal, any small dip there being towards the sea, the oil has in all probability oozed out of the beds in the same way as it does in the cutting previously mentioned.

Origin. From various small pieces of evidence which have come under notice, the conclusion has been come to that the oil is entirely derived from the Beach Deposits. These are as follows:—These beds possess an extremely rich fauna, and being in fact full of fossils, have undergone a destructive distillation by the heat generated in the earth-movements which produced the numerous faults in this region, and formed the Gulf of Suez. As a proof of the formation of the oil in these beds, it

may be mentioned that sulphur is found in minute crystals mixed with the bitumen, etc., on the sides of the cutting in the coral rock. If the source of the oil were from below, then the beds of gypsum (which is a very porous rock) would hold more oil than this beach limestone, which in many places is fairly compact. This is not the case, for, wherever the gypsum has been examined, no trace of oil or bitumen has been found.

The evidence for the formation of the gypsum from above, although not seen in Jebel Zeit, is found in Sinai, where the same beach deposits overlie gypsumised limestone, which, when followed down to lower beds, was seen to be normal limestone and marl.

It thus seems probable that the source of the oil being in the Beach Deposits, the supply will not be in sufficient quantity to pay the working. Moreover, since these Beach Deposits have taken part in the movements by which the Gulf of Suez was formed, and the main mass of these beds has been thrown down under the sea, it follows that the most likely place to find the oil collected is in some place in the bed of the Gulf. Such being the case, a strong supply cannot be looked for in any bore which may be put down, as the collecting area is so very small.

With regard to the plain to the west of Jebel Zeit range and between it and the main igneous range, there seems to be no evidence to show that petroleum is likely to be found there. Traversing this plain in a north-westerly direction, it is found that the Beach Deposits are either absent or occur only in small patches, a thin surface-covering in many cases being all that is present. The main part of the plain, examined in a traverse to Bir Abu Nakhla, is composed of the gypsum and gypseous marls of the base of the Eocene, masked in many places by a cap of igneous gravel and sand. As this well was approached these beds came to the surface, the Cretaceous and Nubian Sandstone following in due order. The Beach deposits only form patches on the low hills around and are evidently very thin, although they thicken away to the north. If, as is stated earlier, the petroleum comes from the Beach deposits, it is doubtful if any will be found in this plain. As far as indications go there is none.

Sinai.—There is only one place where signs of petroleum were seen, viz., in Wadi el 'Araba where it cuts through the igneous range and falls into the sea. Here patches of the white Nubian Sandstone were rendered black by hydrocarbons, and there was a strong smell of petroleum at the place.* This rock passed under Beach deposits, its beds being tilted

* A sample of this rock was analysed and yielded 8% of organic matter.

at a high angle and faulted down towards the sea. There is only a very small area here. In the Beach deposits nearer the sea were found small pieces of sulphur and calcareous sand cemented together, in this particular the conditions being similar to those at Jebel Zeit. It thus seems probable that the petroleum in this case has also been derived from the overlying Beach deposits.

*Jemsa.**—Here in the hills immediately behind the houses which were occupied by those engaged on the works, the limestone in places gives a strong smell of petroleum when struck with a hammer. When the sun is shining a smell of petroleum is noticed in the air, but whether it comes from the rocks or from the old well it is difficult to say. Except for the signs above-mentioned, none are met with in the underlying beds, which are in all probability altered Esna shales. On the side of the headland where the wells were opened, Beach deposit is laid against the older rocks at a high angle; in this there were a few traces of hydrocarbons. It is thus possible that the source of the oil is likewise in the Beach deposits.

The headland of Jemsa is evidently an anticline which has been breached by the sea, as it was gradually elevated from under the waters. That it has been covered by Beach deposits is almost certain as is shown by the conversion into gypsum of a great part of it. Quite recently it has been an island, and during that period must have been exposed to the fury of the waves, its cap of younger beds being removed.

As far as a source of petroleum is concerned, it is difficult to see whence it can be derived, as the limestones which have been gypsumised show no signs of hydrocarbons and the unaltered rock is specially poor in fossils.

DETAILS OF BORINGS AT JEMSA AND JEBEL ZEIT.

WELLS AT JEMSA BORED BY M. DE BAY (12·5 metres apart).

	Metres.	
Coral, gravel, etc	4·00	4·00
Limestone pebbles and blue clay	1·50	5·50
Blue clay.	2·65	8·15
Crystalline limestone	0·95	9·10
Sandy clay	0·60	9·70
Crystalline limestone	1·45	11·15
Sandy clay	0·40	11·55
Crystalline limestone	0·11	11·66
Bituminous clay	5·24	16·90
Sandstone	5·95	22·85
Clay	0·40	23·25
Limestone, siliceous	8·10	31·35
Clay.	0·80	32·15
Limestone	3·15	35·30
Limestone	5·48	40·78
Continued to hard sandstone	56·00	60·00

*Plate VI.

Jemsa and Zeit Wells, from Dixon Bey.

Jemsa Bore No. 1.

	Metres.
Hard dark-grey coral	0 to 4·5
Silicified light-grey coral with small fissures...	10·75
Compact white coral.	12·
Compact white coral, darker	13·75
Compact white coral, more compact and darker.	15·2
Silicified coral with small crevices containing petroleum.	18
Silicified coral but more compact	20
Crevice	27
Hard silicified coral	28
Fine crumbling coral	29·25 to 30·1
Crevice in hard siliceous limestone showing no trace of fossils but containing slight traces of oil	31
Do. but softer and more oil	32·6
Blue clay with strong smell of gas	34·6
Do. with a quantity of petroleum	36·1
Close-grained coral and a large pocket of petroleum which spouted	38·5
Coral stone with petroleum in it	52
Coral stone and clay	59
Coral stone with petroleum in it	64
12·5 centimetres of ozokerite	81 to 82·3
Several small veins of ozokorite	113
Coral stone without oil in it	129·5

Jemsa Bore No. 2.

	Metres.
Silicified limestone	13
Blue clay and stone	20·5
Hard coral stone	49
Blue clay with oil in it	53·5
Sand and blue clay	59·5
Coral	91
Clay and coral	105
Blue clay and traces of oil	145
Blue clay with slight traces of oil...	213·25
Sand and clay with oil	238
Sand and heavy oil in it	256
Gypsum	274·5
Down to 613	

Jemsa Bore No. 3.

	Metres.
Limestone and yellow clay,...	9
Siliceous coral...	19
Clay, gravel and signs of oil	41
Clay and sand...	44
Siliceous coral...	46·25
Clay and stone	71·5
Blue clay and small stones...	96
Black clay and small stones...	122
Stones and clay	134
Clay with layers of stones and traces of oil	193

Jemsa Bore No. 4.

	Metres.
Coral with sulphur veins	9
Coral...	12·25
Coral and clay...	24·5
Clay and traces of oil	27·5
Clay and oil, small quantity...	33·5
Coral limestone	36·5
Limestone and red clay...	46·8
Coral and veins of oil running through it...	47·5
Coral and veins of oil running through it...	49
Clay...	67
Clay and gypsum	97·5
Siliceous coral and gypsum veins...	109·75
Clay and stone and traces of oil...	116
Clay and stone and traces of oil...	134

Zeit.

	Metres.
Gravel	3
Gravel and sea-shells with slight show of oil	18
White coral with veins of sulphur	26
Coral mixed with gravel	30·5
Gypsum, very hard	32·5
White coral	44
Coral, white and black mud...	49
Sandstone and coral	53·5
Flint stone and coral with some blue clay but no gas	55
White coral	61
Sandstone and little white coral...	71·75
Sand, and part clay	76
Stone and clay	79
Clay and slate...	99
Stone and slate	106·75
Stone and clay	149·5
Stone and coral	198
Stone and crystalline rock	213·5

An examination of the records of the various borings is instructive as supporting the theory advanced by the Geological Parties, viz., that the oil is produced only in the Newer Tertiary beach deposits. Taking M. de Bay's two wells at Jemsa, which were only 12.5 metres apart, there is a succession of beds which can be matched in the Miocene and Pleistocene plateaux near Abu Sha'ar. The whole of the beds passed through are of that age. The thicknesses given are greater than anywhere else, but this is explained by the fact noted on the spot, that the beds were inclined at a fairly high angle. It is also a significant fact that as soon as sandstone was struck the boring was discontinued, evidently because this rock was expected to yield the oil, and proved barren.

Taking next those bored by the Americans under the supervision of Mr. Tweddale, the same facts come prominently forward.

No. 1 bore throughout its whole depth of 129·5 metres passes through Beach deposits in which coral occurs again and again.

Bore No. 2 is interesting as being the one which was carried farthest down. The record only shows the beds passed through down to 274 metres, and these are evidently Beach Deposits.

It may be that below these beds towards the limit of the bore (613 metres) Eocene beds were entered, but as the record and specimens are lost, it is impossible to say, the most important fact being that the oil-bearing strata were of the Newer Tertiary series. Bores 3 and 4 were also in the Beach Deposits.

Turning to the boring at Jebel Zeit, the same record appears, the beds being in all probability the same as those in Jemsa. The curious fact about about this well is that, although bored quite close to pools into which petroleum was oozing, no trace of oil was found except in the first 18 metres, as has been pointed out by Col. C. E. Stewart.

On examining all that has been written on this region, the conviction grows that owing to a wrong hypothesis as to the source of the petroleum, a good deal of money has been needlessly spent in putting down bores to tap a deep-seated oil-bearing stratum. Mitchell in his report in 1887 stated, that as the oil-bearing strata in America were of Devonian age, the oil of Jemsa and Jebel Zeit was most likely to be found in strata of the same age, and as Nubian Sandstone occurred in the neigh-bourhood, and some beds at the base of this formation occurring in Wadi 'Araba had been shown to be of Carboniferous and possibly Devonian age, he assumed the presence of these rocks in the neighbourhood of Jebel Zeit, and accordingly advised boring until this sandstone was reached. As far as can be found, there were actually no grounds for this advice, the presence of oil in the Nubian Sandstone being purely hypothetical. As has been already said, all the evidence points to the Beach Deposits as being the source of the oil, therefore as the area covered by the oil-bearing beds is very small, the probabilities are against the finding of a supply in paying quantity and likely to last any time. T.B.

*Memorandum on Analyses of Petroleum**—(1) There are three separate analytical reports—all three differ.

(2) Presumably the three reports all have reference to the same petroleum—this is not stated.

* By A. LUCAS, analyst to the Survey Department.

(3) The three reports are all drawn up differently, and there is no common basis on which the figures may be satisfactorily compared, in one both the specific gravity and the boiling point are given, in the second, only the specific gravity, and in the third, neither.

(4) Placed side by side the various results are as follows:—

PRODUCT.	Khedivial Laboratory.	L. Sigreux.	Rave, Annez & Co.
	%	%	%
Essence (Essence Minérale, Huile Volatile)	2·4	Trace.	5·5
Pétrole Lampant (Huile Lampante)	14·5	22	—
Kérosène	—	—	22·5
Huile Lourde	—	13	—
Huile de graissage (Huile à graisser)... ...	—	8	40
Goudron (Bitume)	—	87	32
Produits passant au-dessus 200 (densité supérieur à 800)	78·0	—	—
Résidu charbonneux	4·6	—	—

(5) The above table of results may be translated as follows:—

ANALYST.	Naphta.	Burning oil.	Lubricating oil.	Residue.
Khedivial Laboratory	16·8	78·0		4·6
L. Sigreux	22·0	13	8	57·0
Rave, Annez & Co.	5·5	22·5	40	32·0

In the Khedivial Laboratory report it is stated that no examination was made of 75% of the sample beyond that it had a specific gravity greater than 0·800 and a boiling-point higher than 200. In the absence of further details it is impossible to arrive at any idea of the true value of the sample, and hence the report, being incomplete, is comparatively useless.

The report signed L. Sigreux must be entirely disregarded: it is worded so loosely that it is quite impossible to discover what it means—the figures may be perfectly correct but in the absence of further information they are meaningless. "Huile lampante and Huile lourde" are terms too vague for a scientific report; to determine what is intended, it is essential to know the specific gravity or boiling-point.

The report of Rave, Annez & Co., is the only precise and business-like one (of its accuracy of course I cannot speak). This gives 22·5 per

cent of burning oil and 40 per cent of lubricating oil. Any petroleum giving these results ought to be valuable provided the separate fractions can be isolated and purified readily.

It is to be noted that the residual bituminous matter (32% according to one report, 57% according to another) is higher than is usually the case either with Russian or American petroleum.

Petroleum.—While it is thus seen that the result of practical research and general theoretical deduction have led the writers to unfavourable conclusions with regard to the petroleum supply, the interesting fact remains that it is present at Jebel Zeit, and that its existence at this locality has been variously accounted for. Fraas* was the first to give a pronounced geological opinion, stating that the petroleum of Jebel Zeit, which was then being worked by the Marquese de Bassano, was in the closest connection with the coral-reef, the petroleum floating on the surface of sea-water filling holes dug in the reef itself. He was strongly of opinion that the only possible source was the decomposition of the organic remains in the reef itself and in its enclosed lagoons, and condemned the policy of the French Engineers who were cutting trenches towards the porphyry hill range, to a depth of 10 metres, and attempting thus, on wrong principles, to drain a source which contained no oil whatever. In fact the Chief Engineer was working under the impression that the petroleum was not in the reef itself, but occurred on the boundary of the porphyry range.

In 1885, M. Barois presented a "Rapport sur les Recherches du Pétrole de la Mer Rouge, etc." which deals admirably with the facts regarding its occurrence at Jebel Zeit, and at the same time treats the question of origin with caution, pointing out, however, that the oil differs considerably from the American varieties, being better for the production of paraffin and the heavy oils. In 1887, L. H. Mitchell published a report which has the merit of introducing a new theory of origin, and viewing the petroleum question from a most optimistic standpoint. From a purely geographical point of view, his results are instructive, but his theoretical conclusions differ in almost every respect from those of the writers. Thus, the very groundwork of his theory assumes that the major portion of the granites, etc., have been introduced into the sedimentary rocks after the deposition of the Upper Miocene series, producing the dislocations which play so great a part in this region. Mitchell writes thus: "On account of the intrusion or eruption of these crystalline rocks, the sedimentary beds were tilted at different angles,

* *Aus dem Orient*, p. 191. etc., 1867.

giving rise in them to seams and fissures connecting the petroleum deposits below with the superior strata or surface of the ground above." He thus assumes the existence of petroleum deposits between the igneous rocks and the main series of sedimentary beds, and accounts for the presence of the free or liquid petroleum at Zeit, etc., as being due to the pressure of gases generated and confined in connection with the petroleum below. Finally, the petroleum deposits themselves are assumed to be in the great Nubian Sandstone area, which Mitchell concludes from Schweinfurth's discoveries in Wadi 'Araba to be Devonian in age, so that the age of the source of petroleum is the same as that in America. It is only necessary here to state that as the writers of this report hold that the evidence shows the igneous rocks (in the main) not to be intrusive into the sedimentaries, that the dislocations are due to faults, and not to eruptions, that the Nubian Sandstone does not contain petroleum, while the latter is forming in the coral-reef, it will be readily understood that they are unable to accept Mitchell's fundamental and favourable conclusions.

In 1888, Colonel Stewart, C.B., at the request of the Government, published a report on this district which throws but little fresh light on the subject, the general impression left after reading it being that Mitchell's geological conclusions had favourably impressed the writer, while his own observations were unsatisfactory in character. Recently, the subject has been attacked from the much-needed chemical point of view, and the results strikingly support the opinions expressed by **Fraas** and held by the Director of the Survey and the writers. The first of these is by Dr. J. Jacunski, and forms the subject-matter of his doctorial thesis, being divided into two parts, the first part* being the one of special interest here, and contains many interesting points, which may be here briefly examined. Petroleum consists in the main of carbon and hydrogen combinations belonging either to the methane ($C_n H_{2n-2}$) or the $C_n H_{2n}$ series, and not only the oliphatic olefine, but also the cyclic naphtha combinations. There may be also present members of the aromatic series, and more rarely oxygen and nitrogen compounds. The existence of nitrogenous combinations is especially important, as they are albuminous, that is, in the form which is a principal component of animal organisms. In succession, Jacunski discusses and puts on one side the view of derivation of the petroleum from plants, and the inorganic hypothesis of Mendelieff, which derives its origin from the decomposition of metal carbides by heated waters at great depths.

* "Untersuchung eines Erdols aus den Korallenriffen des Roten Meeres etc." (Published in Freiburg, Switzerland, Buchdruckerei Gebruder Fragniere p. 56).

Thus the conclusion is arrived at that the origin of the oil must be sought in the decomposition of animal remains, as asserted by Von Buch, Hofer, Wrigley, and others. But this theory has always been met by the difficulty, that all the natural bitumens contain little or no nitrogen compounds, whereas these are extremely abundant in animal products. This obstacle has been overcome in a two-fold manner by Prof. Engler, who has recalled attention to the fact that the nitrogenous portions of animals rapidly undergo decomposition and breaking up, while the fats are very stable, and that further the latter undergo direct alteration under pressure and heat into petroleum.

The principal chronological succession of events is summarized by Engler in his great work "Das Erdöl" as follows:—Decomposition of the nitrogenous substance of dead animals by decay and decomposition leaving the fatty material behind, alteration of these fats under pressure and warmth, in part by pressure only, into Proto-Petroleum ("gesättigte" and "ungesättigte" hydrocarbons, mainly "siedend" at 300°), and gradual passage of the "leichteredenden, ungesättigten" hydrocarbon of this proto-petroleum into the heavy and "hochsiedende lubricating oils.

The principal facts noted by Jacunski are as follows: "The oil from Gemsah shows in reflected light a deep brown colour. The oil is very thick, at 0° it is solid, but there is no separation of paraffin. The specific gravity is 0·9860 at 18° C. and, owing to reasons mentioned in the paper, distillation is difficult, while at a 100° C. a small amount of sulphur is separated out. The oil of Jebel Zeit is slightly lighter, having specific gravity 0·9501, and does not contain so much sulphur as that of Gemsah.

As a result of many analyses the following average composition is given:—

	Petroleum of Gemsah.	Petroleum of Zeit.
Carbon	83· 2%	83·95%
Hydrogen	14· 3	13·75
Ash	0·36	0·43
S...	2·45	1·00
N...	0·30	0·60
	100·61	99·73
		100·00
	Loss or oxygen......	0·27%

As the oil first begins to boil at 200° C. and separates but little paraffin, it can only be employed as "lubricating oil" or as fuel (for ships, locomotives)".

This valuable paper is supplemented by one from Prof. C. Engler himself,* in which his previous conclusions are brought forward in a general form, and it is shown that frequently there is close connection between petroleum and strata rich in organic, especially animal, remains. The more purely geological student may be grateful to him for giving so firm a chemical basis to a conclusion which seems irresistible, at least in the case of the petroleum of Jebel Zeit, that it is the direct, result of the decomposition of the rich fauna which abounds and has abounded in the past in the lagoons and interstices of the present and raised Newer Tertiary coral-reefs. W.F.H.

Section XII.—INFLUENCES GIVING RISE TO THE EASTERN DESERT STRUCTURE.

This subject has already been treated in an excellent manner by Prof. Walther in his two important memoirs.† In the present memoir it is proposed to work from the large determining factors to the smaller influences, and when considering the latter, the above-mentioned works will be frequently referred to. The two great factors which have determined the structure of this portion of the desert are: (1) Geological structure, and (2) Tectonic disturbances. If it were not for the latter the area under consideration might be briefly described as the northern end of an ellipsoidal dome, the central axis running north-west-south-east consisting of the oldest rocks, viz., igneous and metamorphic, while round them the Nubian, Cretaceous, and Eocene beds are laid in regular succession. As a result we have on the west and north a similarity of feature, viz., the jagged peaks of the Red Sea Hills being separated from vertically-walled Eocene limestone plateaux by low tracts, the regions occupied chiefly by the more easily decomposable sandstones. *Thus, the primary features of the Eastern Desert are determined by the geological structure and the nature of the rocks themselves*, and are arranged symmetrically to west and north, the granites producing jagged peaks, the metamorphics more rounded purple-coloured chains, the sandstones long valleys or brown-red plateaux, the Cretaceous, and especially the Eocene, the familiar steep-walled plateaux so familiar in the Nile Valley itself. To the east this

Primary features determined by geological structure.

* *Berichte Deutsch. Chemischen Gesellsch.* Jahrg. XXXIII. Heft I. Zur Geschichte der Bildung des Erdöls pp. I-21.

† *Die Denudation in der Wüste*, Leipzig, 1891 (XVI *Bd. Abhandl. math. phys. Classe d. Konigl. Sachsischen Gesells, der Wissenschaften*, pp. 347-569) and *Das Gesetz der Wüstenbildung*, Berlin, 1901, pp. 175.

regularity is lost, although the rocks forming the country are absolutely identical in their general outlines with those occurring on the western side. This change is due to the influence of tectonic disturbances, resulting from folding and faulting on a large scale, and the consequent differential movements due to the interplay of strata of different structure. These have been frequently referred to in the previous pages, and it is therefore only necessary to recall the production of parallel and repetitional ranges in Jebel 'Esh and Jebel Zeit, with the predominance of linear arrangement (largely north-west and south-east) both here and towards Qosseir, and also the existence of the remarkable tilted and folded sedimentary regions in Jebel Duwi, Um Tagher, etc., in which each of the above-mentioned geological formations is represented by its typical surface-characters.

But the regular arrangement on the western side has been here shown to be in certain respects purely superficial, the cliff-structures of the Eocene plateaux being in all cases, where studied, intimately connected with faulting on a grand-scale, the great longitudinal valley of Wadi Qena owing its origin in large measure to tectonic movements, while the probable importance of transverse fracture has been already insisted on. Thus, going a step further, *the general structure of the Eastern Desert is due to tectonic disturbance and the character of the rocks, which form the surface beds.*

But the problem goes deeper, for the question at once arises, why are the granite peaks so often jagged, the sandstone regions connected with valleys, and the limestone areas such perfect plateaux? The answer to this question lies less closely to the surface, and demands a careful study of the meteorological activities in the area under consideration.

Before dealing with these, a question of nomenclature demands some attention, as at present it is usual to group three very distinct types of country under the common name of "desert," whereas the only feature in which they agree is their being situated within the zone of minimum rainfall. This subject has been discussed with Beadnell, who has had very wide experience of the Western Desert, and the following classification is now suggested. The rainless zone is divisible into three regions, each having its special characteristics. (1) The Desert is that vast plateau region stretching far to the west of the Nile, unbroken by any elevation (or at most by low hillocks which by refraction become enormously exaggerated) and which consists either of a rocky limestone floor or of sand-dunes arranged in a linear manner, and having this floor as their basis. In this desert occur (2) Depressions, the well-known

Oases, which have been so ably dealt with by such writers as Rohlfs, Zittel, Nachtigal, not to mention many distinguished French travellers in similar regions further to the west, and whose origin has been carefully reconsidered by Beadnell * in a paper read recently before the Geological Congress at Paris as well as in the published Survey Report.† Finally, there remains (3) The Wilderness, to adopt the well-known biblical term, the region of wild peaks and sinuous valleys, of rambling hills and deep ravines, where even in the broadest plains elevations are everywhere visible, and in almost every ascent the eye wanders over a bewildering maze of ranges of the most complex character and colour. Such an area is the one now under discussion, differing in every essential particular from those previously described.

What are the great influences at work then, in shaping and forming the wilderness into its manifold shapes and outlines? Prof. Walther has struck the right keynote when he classifies them as follows:—

1. Rain, or speaking generally, water.
2. Temperature variations.
3. Weathering (in the sense of chemical action).
4. Plant-growth.
5. Wind.
6. Electricity and ozone.

1. *Action of Water.*—Nothing is more striking than the general impression left on the mind of the traveller that water-action has been everywhere active in the desert valleys, and those who have seen the rain-storms in actual progress, will be fully ready to accept Walther's dictum, that "Certainly no portion of the African desert is absolutely rainless, only regular rainfall is wanting; but the rare storm-rains (*Streich-regen*) come down with great force and are of a character to produce greater mechanical results in a short time, than would the same quantity of rain if it were distributed over a number of days." In the Eastern Desert itself there was little opportunity of studying this fact, but in Sinai it was brought home in the most startling manner on many occasions. The suddenness of the storms was well illustrated by the objection of the Arabs to camping in a narrow ravine, even though the night seemed to be closing in without any sign of a cloud to disturb the serenity, while their local distribution was illustrated on many an occasion, and especially in Wadi Letih, where on one side of the valley, the rain was coming down in sheets, every gully was an waterfall, and huge boulders were being rolled down, producing a thundering sound like the roar of an Alpine stone-avalanche. Two hours later, a water-

* Recent discoveries in the Nile Valley and Libyan Desert, 1900.
† Survey Reports on Dakhla and Farafra Oases, 1899.

fall was still pouring over a rocky ledge into the main valley, but within a few yards no traces of the water were visible, all having been absorbed by the dry earth. Words fail to describe the intensity of the rain and the grandeur of such a storm, the roll of the thunder being almost drowned by the tremendous volume of sound produced by the drops falling on the rock, when every loose fragment is swept into the gully before the resistless power of the water. The action of denudation on the summits is greatly increased owing to the lack of a soil-covering as well as the effects of decomposition to be subsequently considered.

What are the actual effects of rain in these regions ?

1. The jagged nature of the granite peaks results directly from the combination of three actions, insolation breaking up the polychrome granite, while rain-streams rush down the steep slopes due in the first instance to faulting, taking advantage of the various fissures in the granite itself. The results are well shown in the picture of El Shayeb* where the grooves forming such conspicuous features in the mountain side are gullies, filled with boulders which have been undoubtedly rolled down during storm-periods. To the action of water, too, must be traced the long and thin nature of the crests, which are generally a mere knife-edge broken up into a series of rocky projections, and bounded on both sides by precipitous slopes. Where the granite has been lately covered by doleritic rocks, or the massif is more square in outline, the effect is different, the covering rock as it wears away, leaving a more plateau-like granite surface which, by the well-known process of scaling, gradually assumes the dome-shaped and rounded forms familiar to students of this region, which is well shown in the illustration of Jebel Gharib.†

Potholes in the granite.

But there is another striking evidence of the action of water to be seen in valleys of the granite countries, viz., "Potholes." Typical examples of these are seen in the valley of Um Disi where there are several pools of water in large oval basins so well polished that it is dangerous to walk on the edge, and still containing the boulders by which the wearing out and polishing were done. Such holes are by no means uncommon in this area, another example being met with at Bir Gattar, a pool up in the hill, the way to which is so smooth as to be impossible to anyone wearing boots, and only accessible to the Bedawin walking barefoot.

The metamorphic regions show less direct evidence of the action of water, but on the other hand this agency must be largely effective in producing the remarkable ridges and gullies due to the dykes piercing

* See Photogravure of J. el Shayeb, p. 40.

† See Photogravure of J. Gharib, p. 33.

the other igneous members. While temperature variation breaks up the granite more rapidly than the felsites, leaving the latter standing out from the surrounding surface, the basic rocks in many cases, being of complex mineral structure, break up readily, and the rushing water finds its natural outlet along these channels, which sometimes become natural roads enabling summits to be reached which would otherwise be only accessible after dangerous climbing.

No less important is the action of water in the sedimentary districts, but here the action is of a different nature. The water collecting on the summit of a plateau simply sinks into the dry earth if the level be the same throughout, but on any fracture being produced it tends to run along the resulting channel and gradually cuts it back, producing the deep ravines so characteristic of the borders of the Eocene plateau. Although in the majority of cases the wadis in the Eastern Desert owe their origin primarily to faulting and tectonic disturbances, still it is to the action of water that they owe their final sculpture and form, though in the former, wind may have played a subsidiary part. No one traversing the wadis in the sedimentary area immediately adjoining the Nile valley, can help being struck by the evidences of former water-action, as seen in the shape of deep "potholes" with almost vertical, polished sides carved out of the limestone floor and containing in nearly every case the rounded boulders by whose agency the work of grinding was performed; or again, by the curious nodular appearance produced in the polished bed of the wadi by the unequal wearing of the rock; or the smooth surface of the small waterfalls which, owing to a bed of greater hardness in the rocks forming the sides of the valley, suddenly bring the traveller to a standstill and in many cases force him to retrace his steps, and at the foot of which, hollows have been scooped out by the boulders and pebbles hurled over it during a storm, which form natural reservoirs of water for the supply of the Bedawin who inhabit the valleys. In the numerous, rounded boulders which are met with so frequently in these wadis, one also sees striking proof of the great part which water has played in the sculpture of the plateau.

Another striking example of the action of water is seen in the small, shallow wadis with vertical cañon-like sides which are met with occasionally on the top of a plateau, and which end abruptly in a steep cliff, three to four metres high. In this case the surface of the plateau has been determined by a hard, crystalline bed which has withstood all the action of the different agencies at work, and acts as the floor of the various water-courses which carry off the water. But a line of weakness occurred in the form of a crack along which the water proceeded to act, and once having found an opening it soon broke up the hard bed, and

rapidly removing the softer layers underlying it formed the narrow canon-like gorge above referred to.

In the Nubian Sandstone area too, the steep-sided wadis owe their origin primarily to cracks or joints in the rocks, along which the water formed a channel and eventually carved out the valleys as we at present know them. Here, however, a determining factor of great importance in the shape of the valleys must not be forgotten, viz., the natural jointing of the sandstone rocks, as it is to this that the steep sides of these wadis are due.

Insolation, changes of temperature.

2. *Temperature variations.*—But the action of the rain and water generally would be scarcely seen at all, if they were not assisted by other very potent agents, viz., insolation, and variations of temperature, for, to the action of these are primarily due the main features of the sculpturing of the igneous ranges. Walther, in his work previously quoted, has laid great stress on this, and gone into minute details as to the range of temperature through which the surface of a rock passes during 24 hours, giving observations made by different observers in different places. From these he showed what a profound effect can be produced on the rocks when exposed to this agency for a great space of time.

In the Red Sea Hills, one cannot fail to be struck by the evidences everywhere met with of the changes of temperature, the granite ranges of Gattar and Um Disi in particular showing this specially well. Ascending Wadi Belih, one sees thick cakes (4 to 5 centimetres) peeling off from the main mass, while at the foot of the hills, large slabs are seen which have slipped off. Again, it is only when one tries to obtain a fresh specimen of the rock that it is discovered how profound has been the action of this agent. To all appearence the surface is perfectly fresh, but when it is struck by the hammer it crumbles away into a coarse powder, it being vain to seek for a sound piece in all the rock. Nor is this action confined to the surface, for the same thing is found for several centimetres down. Amongst the basic rocks, too, the same action is met with under a different form; for, whereas, in the granites, the crumbling was chiefly due to the felspar yielding along its lines of cleavage and thus setting free the quartz, in these rocks it is caused by minute, invisible cracks which, when the rock is struck, cause it to fall into small pieces. This renders climbing on these rocks extremely dangerous, as ledges which look quite safe to walk upon, suddenly give way under the climber to the detriment of his clothes and hands. The surfaces of these rocks also are continually covered by a rubble of loose fragments, which lying on a firm, more or less smooth surface render

the footing very insecure and often give the unwary traveller a nasty fall. Such are the hills of Jebel Zeit, Jebel 'Esh, Jebel Sidri, and those in the neighbourhood of Wadis Belih, Fatiri, Safaja, Semna,and Wasif.

3. The action of these agents depends upon, and is controlled largely by the mineral composition of the various rocks composing the hills. Taking the different types of granite in succession, it is seen that they are affected differently, and the same can be said of the basic rocks. The red granite which forms all the high hills of the watershed is a highly quartzose, mica-poor rock rising in sharp jagged peaks, and forming rugged almost inaccessible ridges. On account of its high silica-percentage, and the relatively small quantity of felspar, it offers greater resistance to the weather, and stands out sharply from its neighbours in steep-sided peaks bristling with large grains of quartz which break out under the boot and render the footing insecure. The edges of the ledges are also treacherous because of their fresh-looking appearance, and when laid hold of crumble away in the hand, often giving the climber a number of unpleasant slips. The pink porphyritic granite and the grey variety on the other hand behave in a different manner. They are both relatively poor in quartz compared to the red variety, and consequently being richer in felspar and mica are much more amenable to the action of the agent under consideration, on account of the numerous planes of weakness which exist in the two latter minerals. Another factor likewise comes into play which must be reckoned with, viz., the different coefficients of expansion of the various minerals.

As a result of the combined action of the various forces mentioned, these rocks scale off and crumble more easily than their red congener, and assume the dome-shaped, rounded form with which everyone is so familiar in a granite area. The felspars and mica being flaked off in thin laminae are carried away by the wind and rain, leaving the rounded grains of quartz, like so many peas, scattered over the surface of the rock. It is this radical difference between these rocks that accounts for the fact of the red granite forming the high ridges while the lower foot-hills are formed of the felspar-rich granite.

In the basic rocks, however, the action of the changes of temperature takes effect not on account of the cleavage-planes of the felspars, but is due to the difference of the coefficients of expansion of the constituent minerals and the hemicrystalline matrix in which they are embedded. Two distinct types of weathering in this way are met with, viz., the splitting off of small fragments by cracking, and the tendency to scale off in concentric shells. The former type is met with in the lava flows

and more glassy dykes; while the latter occurs in the more crystalline intrusions. In the latter type, however, moisture in all probability plays a fairly important part.

4. Another determining factor in the sculpture of the country is the large number of dykes and intrusions along certain well-defined lines, which by their regularity give rise to the peculiar type of scenery which has been called the "Dyke Country" in the field-notes. These having been injected into cracks caused by tectonic movements, and being of superior hardness, and therefore better fitted to withstand the weathering agents, the rock between them gets gradually worn down into a valley into which the drainage runs and thus hastens still more the work of denudation. This type of scenery is met with extending over large areas, often further than can be seen from a hill on the border of this maze of ridges, and is a peculiarity of certain districts in which the grey granite forms the country rock.

5. *Wind.*—Under this heading is included the combined action of wind and sand. Walther in his "Die Denudation in der Wuste" divides the work of the wind into two. viz:— **Wind and sand.**

(*a*). Transporting action.

(*b*). Wearing by means of sand.

In the work above referred to he employs the term "Deflation" to describe the denuding activity of the wind independent of sand-action, and he lays stress on this action as being of great importance in the formation of the desert. By "deflation is understood, the breaking off of particles loosened by the sun and their transportation to another place. On this point, the observations in the Eastern Desert do not bear out this idea, and the writers are inclined to assign a very secondary position to this action of the wind.

Transportation action.—No one who has had the misfortune to be caught in a dust-storm in the desert can have any doubt of the carrying action of the wind. The first indication of one of these storms apart from the meteorological conditions, is the appearance of a slight yellowish haze on the horizon which gradually gets denser as it approaches. In a short time traveller finds himself suddenly engulfed in clouds of extremely fine dust which blot out everything from view. Accompanying this dust is a strong wind which hurls the fine particles into the eyes and nose of the unfortunate individual, so that he has a difficulty in breathing, and is absolutely compelled to keep his eyes shut. Under these circumstances the only course open is to find a shelter and wait till the main dust-cloud has passed. Following this dense dust-cloud and accompanying it to a certain extent are the true

the footing ... and hurled against the fall ... It is this part of the storm ir

sand-grains, which are caught up by the wind, and hurled against the face, dealing stinging blows like small shot. It is this part of the storm which erodes and wears down the rocks.

But in order to enable the wind to do efficient work, two things are necessary, viz., a supply of sand, and secondly an open space, such as a plain or plateau. Before going on to the work of the sand, it is necessary to say a few words about its origin. Walther,* says that the chief source of the sand is the granite area, while the Nubian Sandstone plays a very unimportant rôle in the production of wind-borne sand. With this statement the writers entirely disagree and attribute the source of the active sand to the disintegration of the Nubian Sandstone or similiar sandy beds. Anyone who has ever passed over a Nubian Sandstone area cannot fail to have noticed the masses of quartzite pebbles covering the low ground at the foot of the escarpments, which are the remains of the sandstone, the smaller grains having been carried off by the wind. It is a fact also that in the Eastern Desert the main mass of the sand is accumulated in the Nubian Sandstone area and in the regions adjoining it, while in the granite areas no dunes exist. Moreover, while camped among the granite hills the writers have seen sandstorms in full blast in the open plain where sandstones and sandy beds exist, while amongst the granite hills there was not a trace of sand. Perhaps the most convincing argument in favour of the Nubian Sandstone being the main source of the sand, is the presence of large wind-swept plains in the middle of that area from which all the beds have been removed and heaped up in the adjacent wadis. Also it has been noticed that while a sandstorm was in progress in the open plain, although there was a strong wind (too strong to allow the tents to stand) still there was scarcely a particle of sand or dust moving. Moreover all the writers' experiences of sandstorms took place in the neighbourhood of Nubian Sandstone areas, *e.g.*, in Wadi Qena, and the Coast Plain to the south of the Jebel 'Esh-Mellaha ranges, the sand in both places coming from the direction of the sandstone.

As has been already stated, it is on the open plains and on the cliffs bounding them that sand-action is best seen. There one sees "dreikante" in every stage of formation, where limestone is available. On the Coast Plain on the eastern side of the Red Sea Hills to the north of Wadi Barud, wherever crystalline limestone crops out, it is polished and grooved in a remarkable manner; along the eastern flank of Jebel

* "Uber Ergebnisse einer Forschungsreise auf der Sinaihalbinsel und in der Arabischen Wuste" (Verhandl. den Gessels. f. Erdkunde z. Berlin, 1888 Bd. XV. No. 6).

'Esh, granite and dolerite boulders are rounded and polished; while in the valley, between this range and that of Mellaha, the sandstone itself is rounded off and worn out in curious holes and eddies by the sand. All along this valley the fragments of the andesitic rock brought down by the water have acquired a fine vitreous polish.

Again in Wadi Qena the work of the wind and sand are well shown, in the cutting out of hollows in the Pliocene limestones, and also in the general rounding off of the low hills of that rock. But the most striking examples of wind and sand-action met with are the cirques of the outlier of Abu Had. Along the steep precipitous cliff facing Wadi Qena are a number of semicircular indentations in the hard flinty series of the Eocene, in the walls of which the flinty layers stand out in relief while the softer limestone is eaten out. This plateau, lying as it does more or less in the path of the storms which sweep down Wadi Qena, is exposed to the full force of the blast and as a consequence is well placed to illustrate sand-action. Being traversed by cracks, caused by the movements during the period of faulting, the fractures were planes of weakness on which the sand acted, gradually wearing out the semicircular areas now seen in the cliff. That they are the result of sand being hurled against the cliff, and eventually eddying round in the hollows thus produced seems to be the only explanation and the action of water may be dismissed at once, there being no collecting ground, the surface of the plateau in places not being 100 metres wide. Support is likewise lent to this view by the fact that the opposite face of the plateau although exposed to the wind and sand is not indented, because it faces the north-east and east, and thus does not receive the full force of the storm, although its surface is nevertheless planed off in a wonderful manner. Cirques.

There is no doubt, however, that the most potent results are seen in the low mounds and hills in the valleys and plains where the sand is being driven along with a rushing noise and constitutes a veritable sand-blast, all the inequalities of the rocks being brought out in a very striking manner. Fossils are made to stand out in relief—some being seen standing out on a pedestal of softer rock which is protected by these harder substances—invisible cracks in the boulders are exposed, and their course marked out by a small furrow eaten out along the line, while stones which contain concentric layers of chalcedony and opal have the latter cut out, leaving the former standing to mark the original pattern of silicification.

To sum up, the most important points noted in the previous pages on the Influences which give rise to the Eastern Desert are:—

1. Its geological structure.

2. Tectonic movements, folding and faulting, breaking up the plateau into isolated areas.

3. Water is an active agent in transporting material already loosened by other agents, but is also a powerful factor in sculpturing the hills and wadis by mechanical erosion.

4. Insolation and changes of temperature account largely for the present form of the igneous hills, these agents being also assisted and controlled by—

5. The mineral composition of the rocks and by the difference of their coefficients of expansion.

6. The various dykes which cross the country are strong determining factors in the hill sculpture.

7. Wind is only effective where it has a supply of sand and plenty of space to act.

8. The Nubian Sandstone and not granite is the source of the sand.

9. The Cirques in Jebel Abu Had are the result of sand-action eating away the limestone along previously formed cracks.

W.F.H. & T.B.

APPENDICES.

APPENDIX I.

ANALYSES OF WATERS FROM THE SOUTHERN HALF OF THE DISTRICT.

The following analyses were made by A. Lucas, Analyst to the Survey Department, in May, 1901, from samples collected in the latter part of December, 1896, and October, 1897. The delay in carrying out the analyses was due in the first place to there being no chemist attached to the Survey at that time, and as a consequence the samples had to be handed over to the Laboratory of Hygiene of the Sanitary Department where they had been put aside and forgotten. It will be seen by all who know about water analysis that the true composition of the waters cannot be deduced from the present analyses, as bacteria have undoubtedly been at work breaking up any organic matter which may have been present, and rearranging the composition of the various mineral salts. As a matter of fact the samples were too small to allow of a complete analysis, only the common constituents of the mineral residue being determined.

The waters may be divided into two classes, viz :—

1. Waters from shallow wells or springs in the wadis.
2. Rain-water collected in granite basins in the hills.

Into the first class fall the samples from Bir el Geita, Bir Arras, Bir Dokhan, and Bir Mellaha, while those from Bir Um Disi and Bir Gattar fall into the second.

The following is the composition of those in Class I:—

COMPOSITION.	I	II	III	IV
Total Solids...	119·08	815·24	345·52	230·04
Silica	3·40	2·68	4·14	1·88
Iron and Aluminium Oxides	1·84	1·32	0·48	0·60
Lime	17·08	108·40	32·44	24·08
Magnesia	4·32	53·27	9·85	8·43
Chlorine	21·08	309·06 =Na.Cl. 510·05	94·82	73·75
Sulphuric Anhydride ...	37·60	93·04	92·99	49·53

For localities see section on wells, Part II, p. 253.

I, is Bir Arras; II, Bir Mellaha; III, Bir Dokhan; IV, Bir el Geita.

The analyses are expressed in parts per 100,000.

The following is the probable method of combination in I, III, and IV, the ingredients in II being in such quantities as to make it difficult to calculate a probable series of compounds:—

COMPOSITION.	I	III	IV	V
Silica	3·40	4·14	1·88	—
Iron and Aluminium Oxides ...	1·84	0·48	0·60	—
Calcium Sulphate	41·49	78·73	55·83	61·00
Magnesium Sulphate	12·89	29·35	25·12	7·00
Sodium Chloride...	34·78	156·49	121·72	11·71
Sodium Sulphate...	8·31	47·30	—	14·28
Calcium Carbonate	—	trace	1·83	17·14

V. Is an analysis of spring water from Swindon, 80 miles from London, by Wanklin, converted from grains per gallon to parts per 100,000 for purposes of comparison.

A glance at the table shews that, excepting that of Bir Dokhan, the English water is richer in calcium sulphate. This is as it ought to be seeing it comes from a limestone district, while the others come from the wadi gravels or sandstone where their supply is likely to be less abundant. When, however, the quantities of magnesium sulphate and sodium chloride are compared the English water falls far behind, while the sodium sulphate is medium. Taking the English water as an example of a highly salted water and one which would be regarded as containing too much to be a good potable water it becomes a matter of surprise how people can use the above-mentioned waters at all. The writer has used water from IV for several days, and except for a saline taste and a suspicion of salt in it, it tasted pleasant enough, although tea made from it was not pleasant and produced a feeling of thirst. Sample III (Bir Dokhan), was less pleasant to the taste, being decidedly bitter, the large quantity of the soluble sulphates being accountable for this, while the sodium chloride gave it its brackish taste. Tea made from this water was undrinkable. The water from No. III is the only kind available for the people in the village of El Geita, other wells in use having a larger quantity of salts. As far as is known the people do not suffer in any way from prolonged drinking of this water. Bir Dokhan, although used by the Bedawin for watering their flocks, is not much used by the people except in passing, rain-pools being within easy reach to the south and west. The water from Bir Arras is only used by the Bedawin passing up and down Wadi Qena, and is only found in very limited quantity.

In Class 2 the only samples analysed were those from Bir Gattar and Bir Um Disi, but as the samples were very small, the chlorine and sulphur trioxide could only be determined.

Composition.	Bir Gattar.		Bir Um Disi.	
Total Solids		40·50		28·84
Chlorine		6·32		5·62
	=Na. Cl.	10·43	=Na. Cl.	9·27
Sulphuric Anhydride		2·49		2·19

Analyses are expressed in parts per 100,000.

In Frankland's Water Analysis it is stated that, if a sample of water contains more than eight parts of chlorine per 100,000, it may usually be suspected of organic pollution; in the two samples above-mentioned the quantities are within the limits. It might easily be expected however that, in such a rainless country as Egypt where various salts are in such abundance at the surface, the chlorine ratio might be far above the limit prescribed for England and yet be untainted by any organic pollution. If this were not so, then the waters quoted at the beginning of this account should be veritable sources of all sorts of diseases, which they apparently are not.

APPENDIX II.

Phosphate Deposits of the Eastern Desert.

These deposits were described in the "Report on the Phosphate Deposits of Egypt," Cairo, 1900. At the time of the preparation of this report all the analyses of the samples had not been carried out owing to the specimens being packed up and stored away. Since the issuing of this report, the specimens have been removed to the new Geological Museum, and unpacked there, and samples, from the various places within the area examined have been analysed with the results shown below.

The samples under consideration were obtained from three places, Jebel Abu Had, Wadi Hammama, and Jebel Duwi. In the first area the phosphatic layer occurred at the foot of the main escarpment, and was probably at one time continuous with that at Wadi Hammama. At the latter place the following section was obtained:—

Top.—Surface of plateau formed by a hard, bluish crystalline limestone containing *Ptychoceras*, etc., and passing into a less fossiliferous variety	0·45 metres.
2. Siliceous limestone of a nodular aspect...	1·20 "
3. Phosphate bed	0·60 "
4. Siliceous limestone	0·30 "
5. Phosphate bed	0·30 "
6. Green marl	0·15 "
7. Oyster limestone	1·20 "

In the third area the phosphate bed occurs below thick limestone, and apart from its less favourable position, its value is thus correspondingly lessened. It is from 0·45 to 0·6 metres thick.

Percentage of Tricalcic Phosphate in the Phosphate Beds of the Eastern Desert.

(By A. Lucas.)

Number.	Locality.	% Tricalcic phosphate.
1744	Abu Had...	11·70
1711	Wadi Hammama	50·78
1981	Do.	29·38
1715	Do.	45·65
1765	Do.	43·97
1878	Jebel Duwi	45·10
1942	Do. near Bir el Beida	50·43

The sample from Abu Had is a very poor one indeed, and may be left out of consideration from a commercial point of view. Turning to those from Wadi

Hammama, it is seen, if the second be excluded as probably not a representative sample, that an average of 46·80% of tricalcic phosphate can be obtained. As was pointed out in the above-mentioned Report the difficulties of transport from this place are not great, a fairly good camel road leading into Wadi Qena and on to the Nile.

In the case of the Jebel Duwi samples the average is 47·86% tricalcic phosphate. In both cases the average composition is better than that of the Belgian phosphate deposits, there is thus no reason why they should not be profitably worked, provided that the products were employed in the country, it being out of the question to think of exporting the raw material, since much richer phosphate beds are found in Algeria, South Carolina, and Christmas Island.

APPENDIX III.

PREVIOUS LITERATURE.

The literature relating to the Eastern Desert is very extensive, it having been crossed at various points by many travellers during the present century. The earliest scientific record is contained in the monumental *Description de l'Égypte*, in which De Rozière published several memoirs which are characterized by carefulness of observation and caution as regards theoretical deduction. Of the works which at this period deal with the district under consideration, those given below are the most important.[1-2] 1813-21. *Description de l'Egypte.*

Nos. 2(*a*) and 2(*b*) contain a very complete description of the Nubian Sandstone, whose precise age is, however, left in uncertainty. The description of the Qosseir valley contains much of interest, more especially the conclusion that the Moqattam chain (Eocene plateau of present day) once extended along the right bank of the Nile, but has now broken up, giving rise to calcareous gravels between Bir Ambar and El Geita; the change to sandstone near the latter place, and the subsequent passage from the sandstones to the breccias and quartzose conglomerates, having also been observed. The igneous rocks receive special attention, being broadly divided into (1) Granitic rocks, (2) Breccias and conglomerates, which are shown to be composed of intermixtures of granites and porphyritic rocks of many varieties, and schistose rocks. Of special interest is De Rozière's description of the faulted-in sedimentaries near Qosseir (p. 185), in which he records *Ostrea diluviana* as occurring in abundance. In order to account for the present relations of the strata he suggests that the valleys formed in the schists were filled in by sandstones, the ravines subsequently formed in the latter being in their turn occupied by limestones.

The opening of the third decade of the 19th century was marked by renewed activity in the study of the Eastern Desert, Cailliaud[3] re-discovering the emerald mines of Jebel Zabara and the sulphur beds of Jemsa, while four years later James Burton, accompanied by Wilkinson, began a detailed examination of the whole region, the results being embodied in several volumes of manuscript now preserved in the British Museum. Jebel Gharib having been ascended, the copper mines of Dara were visited, and in 1822 Burton examined the temples at Dokhan and Fatiri, as well as the Roman fort of Deir el Atrash. The only published record of these journeys was that of Wilkinson,[4] in which some of the 1815-24. Cailliaud. Burton and Wilkinson.

[1]1813. DOLOMIEU. "Sur la constitution physique de l'Egypte," *Journal de Physique*, XLII.

[2](*a*) DE ROZIÈRE. *Description de l'Égypte. Antiquités*, Tome X, 1821, pp. 240-265. Description de Gebel Selseleh et des carrières qui ont fourni les matériaux des principaux édifices de la Thébaïde.

(*b*) *Histoire naturelle*, Tome II, 1813.

(*c*) *Histoire naturelle*, Tome XX, 1824, Description minéralogique de la vallée de Qoçeir, pp. 165-195.

(*d*) *Histoire naturelle*, Tome XXI.

[3]CAILLIAUD F., "Voyage à l'Oasis de Thèbes et dans les déserts fait en 1815-1818," Paris, 1821. Rédigé et publié par M. Jomard.

[4]WILKINSON J., "Notes on a part of the Eastern Desert of Egypt with a map of the Egyptian Desert between Keneh and Suez," *Journ. Roy. Geogr. Soc.*, London, 1832, Vol. II., pp. 28-60.

1775. Forskal. 1825. Audouin. principal results are briefly described. Already as early as 1775, the shells of the Red Sea had aroused the interest of the Swedish naturalists, Forskal[5] describing eighteen species in that year, while in 1825 Audouin[6] examined the fine collection made by Savigny during the French expedition, though in Issel's opinion this memoir is not of great scientific value.

1837. Nash. In a short paper Nash[7] regarded the Nubian Sandstone as of Triassic age, while the Nummulitic and Cretaceous beds were classed together.

1835-41. Russegger. Since the French expedition no further work on a large scale had been published until Russegger[8] carried out his well-known exploration of the Nile Valley and Sinai. Though himself but little acquainted with the Eastern Desert, his study of previous literature enabled him to give a brief account of the geology of the Red Sea Hills as far as then known (vol. 3, pp. 351-361). The beds of the limestone plateau between Cairo and Assiut are regarded as being Tertiary, while strata of similar nature to the south are referred to the Cretaceous, as shown on his maps. He also changed his opinion regarding the age of the Nubian Sandstone, at first considering it as Triassic, but subsequently referring it to the Lower Cretaceous, *i.e.*, the Grün or Quader sandstein. Lefèvre[9] had previously justly recognized the close connection of the Nummulitic limestones north of Assiut with those south of that town. Following closely on the publication of Russegger's great work Newbold[10] gave a general account of the geology of the Eastern Desert, etc., this being marked by accuracy of fact combined with great caution in arriving at conclusions with regard to the age of the sedimentary strata, while at the same time A. Roberti edited the diaries of the Italian traveller G. B. Brocchi,[11] who had travelled from Qena to Qosseir, via Wadi Hammamat, and had then followed the coast-line as far as Suez. As a result of his collections seventy-seven species of shells were described from Egypt and Syria by G. Forni.[12] The writer, while noting the great difference between the Mediterranean and Red Sea fauna, believed some species to be common to both.

1842. Newbold. 1841-43. C. B. Brocchi.

1852. Lepsius. The historical knowledge of this portion of the desert was greatly enlarged by the visit of R. Lepsius[13] to Jebel Dokhan and Wadi Hammamat, the archæological results obtained being of much value.

1864-65. Figari Bey. In 1864-65 Figari Bey[14] published the results of his extended travels, and, as Zittel has remarked, it is to be regretted that his lack of scientific training materially reduces the value of his labours, which in view of later works over the same area, are now of little importance, though some of the details and

[5] "Descriptiones animalium quæ in itenere orientali observabit," P. FORSKAL.

[6] AUDOUIN, *Description de l'Égypte*, 2nd edition, Tome XXII. Paris, 1826.

[7] NASH, "On the Geology of Egypt and the Valley of Cosseir," Edinburgh, *New Phil. Journal* 1837, Vol. XXXII.

[8] "Reisen in Europa, Asien, und Africa, unternommen in den Jahren 1835-41," 4 vols., with map. Stuttgart. 1841-49.

[9] *Bull. Soc. géol. France*, vol. X, pp. 144 etc.

[10] "On the Geology of Egypt," *Quart. Journ. Geol. Soc.*, London, 1847-48, vol. IV.

[11] "Giornale delle osservazioni fatte nei viaggi in Egitto, nella Siria e nella Nubia da G. B. Brocchi. Opera postuma. Bassano, 1841-43.

[12] "Catalogo di una serie di conchiglie raccolte presso la costa africana del Golfo Arabico dal signor G. Forni." (Memoria inserita nella *Biblioteca Italiana*).

[13] "Briefe aus Ægypten, Æthiopien und der Halbinsel des Sinai," Berlin, 1854.

[14] "Studii scientifici sull' Egitto e sue adiacenze compresa la Penisola dell'Arabia Petrea," con accompagnamento di carta geografica-geologica. Lucca, 1864-65.

especially his collections remain of permanent interest. The regret is the greater, when we recall that this writer visited the Qena-Qosseir road (pp. 33-40), Wadi Qena and its tributaries (pp. 41-50), and the desert region between Jebels Gharib, Dokhan, and Zeit (pp. 50-60). Among other matters of note he records the occurrence of galena, blende, and calamine (lead and zinc ores) near Wadi Safaja; hæmatite iron near Gharib; the gypsum hills and petroleum near Jebel Zeit; but his stratigraphy is too vague to constitute a material advance. Previous to the publication of this volume, Husson and Figari[15] had published a short account of their journey to Jebel Zeit.

In the year 1864 Dr. G. Schweinfurth began the series of journeys which have proved epoch-making as far as this portion of the desert is concerned, the results of an examination of his shell-collections being published by E. von Martens.[16]

1867. O. Fraas.

Three years later Oscar Fraas[17] followed the well-known road between Qena and Qosseir, but owing to his being ill at the time, his results are not so complete as might have been expected from so keen an observer. He failed to grasp the significance of the Duwi region, while the Nubian Sandstone is suggested as of possible Tertiary age; on the other hand, some facts of value were obtained regarding the Pleistocene fauna near Qosseir, the presence of petroleum at Jebel Zeit being also considered to be due to the decomposition of the fauna of the coral reefs.

1866. Lartet.

In 1866 L. Lartet[18] had formed part of an expedition, which under the auspices of the Duc de Luynes, visited the Holy Land and neighbouring regions. The fine volumes embodying the main results are of great value, containing as they do the first account of one of the most striking of the Rift Valleys, *i.e.* the Jordan Valley and Gulf of Aqaba depression. Lartet[19-20] also interested himself in the age of the Nubian Sandstone, which he regarded as Middle Cretaceous, also noting the important fact that none of the underlying igneous dykes appeared to penetrate it.

1868. Delanoüe and Schweinfurth.

A short paper by Delanoüe[21] is of importance as proving the Eocene age of the limestones at Thebes, the palæontological determinations being by d'Archiac. In the same year Schweinfurth[22] published a detailed paper on plant-distribution in Egypt, Issel[23] at the same time dealing exhaustively with the mollusca of the Red Sea. After referring to the observations of De Rozière, Newbold, d'Abbadie, Rüppel, and Fraas on the sub-fossil reefs, this writer points out that their fauna is somewhat different from that now living in the Gulf of Suez, *Conus, Mitra, Strombus, Cypræa, Cerithium*, and *Arca* being more common while

1869. Issel.

[15] *Bull. Soc. géogr. de Paris.* 2me série, vol. IV, p. 350, vol. V, p. 32 et vol. VI, p. 111.

[16] *Verhandl. d. K. K. Zool.-botan. Gesellschaft in Wien*, 1865.

[17] Aus dem Orient. Geologische Beobachtungen. Stuttgart, 1867.

[18] De Luynes, "Voyage à la Mer Morte."

[19] "Sur une formation particulière de grès rouge en Afrique et Asie." *Bull. Soc. géol. France*, 1868. II sec., t. XXV, p. 490.

[20] "Essai sur la géologie de la Palestine et des contrées avoisinantes telles que l'Egypte et l'Arabie. *Ann. des sciences géologiques*, par Hébert et A. Milne-Edwards. Vol. I, pp. 5-329 (1869) et vol. III, pp. 1-91, 1872.

[21] "Sur la constitution géologique des environs de Thèbes." *Comptes rendus l'Acad. des Sciences*, 1868, t. LXVII, p. 701, etc.

[22] Pflanzengeographische Skizzen des gesammten Nil-Gebiets und der Uferländer des Rothen Meeres, 1868.

[23] *Biblioteca Malacologica.* "Malacologia del Mar Rosso," p. 387, with five plates.

18 genera and 105 species obtained in them were wanting in the gulf. By comparing the raised beaches with the strata in Sardinia, Sicily, etc., he considers that they may be referred to the Post-Pliocene of Lyell, an examination of the Isthmus of Suez also leading him to the conclusion that during the Eocene and Miocene periods the two seas were in contact. At the end of the Pliocene an elevation of the isthmus took place, succeeded by a submergence. A comparison of the fauna of the raised coral reefs and that of the subappennine marls reveals the interesting fact that these are more closely related to each other than those of the present Red Sea and Mediterranean respectively. Issel concludes that the Mediterranean was dependent on the Indian Ocean for its fauna during the Pliocene and Miocene periods (probably the Eocene also), while subsequently it became a tributary of the Atlantic Ocean.

1876. Schweinfurth. Whereas up to 1876, the majority of the travellers visiting this region had followed the better-known roads, Dr. G. Schweinfurth prepared a scheme having as its object the systematic exploration and mapping of the whole of the Eastern Desert. To this period belong several papers which appeared in Petermann's Mittheilungen, written either by him alone or in collaboration with Güssfeldt, but all these deal with districts north of the region considered in this memoir.

Besides these there are others treating of the area covered by the present memoir.[24] Liebisch[25] also describes several rock-specimens, notably the coarse granite of Gattar, and the porphyry of Dokhan.

In 1878 Dr. Schweinfurth[26] gave an elaborate and detailed account of his researches in this portion of the desert (illustrated by a map based on the author's personal survey), which remains up to the present time the most important geographical account of the country lying between the Nile and the Red Sea. Among the major points clearly recognized in this contribution is the non-existence of mountain ranges west of a line joining Suez and Edfu, their place being taken by a plateau, much cut up by water-courses, usually steep-sided ravines terminating in precipitous amphitheatres at their head. The principal valleys are described in some detail, while Wadi Qena is shown to be 230 kilometres long, and to be separated from Wadi Hauaschieh by a low saddle. Finally he notes the dismembered character of the Red Sea Hills, and the importance of the dykes, while the principal mountains between Gharib and Gattar are described at some length.

1878. Klunzinger. Dr. Klunzinger had also availed himself of the opportunity afforded by his residence at Qosseir to make a study of the sea-coast and desert in that neighbourhood, his results being embodied in two important contributions.[27]-[28] While recognizing their general value, there is one important point on which the writers materially differ from him, for he describes the sedimentary region near Qosseir as showing a complete transition (allmähliger Uebergang) from the Cretaceous through the Tertiary to the recent beds, so that (according to him) theRed Sea existed from the Cretaceous period onward and gradually withdrew to its present bed.

[24] *Petermann's Mittheilungen*, vol. XXIII, 1877, X. pp. 387-390.

[25] "Ueber die von Dr. G. Schweinfurth in der mittleren ægyptischen Wüste gesammelten massigen Gesteine." *Zeitschr. der Deutsch. geol. Gesellschaft*, 1877, XXIX, p. 712.

[26] "La terra incognita dell'Egitto propriamente detto." *Esploratore*, Anno II, 1878. Milano.

[27] "Die Vegetation der ägyptisch-arabischen Wüste bei Kosseir." *Zeitsch. der Gesells. für Erdkunde zu Berlin*, XIII, 1878, pp. 432-462.

[28] "Ober-Ægypten", Stuttgart, 1878.

The same writer subsequently dealt more fully with the region round Qosseir,[29] giving a general account of all the important wells on the Qena and Luxor-Qosseir roads, and also to the north of the latter town. The ranges and harbours are also treated in some detail, while the road followed from Hamrawein to Safaja shows that a longitudinal passage exists between the Wadi Semna road and the Coast Plain. The geology is briefly described, most of the dark hills being regarded as diorites or claystone, with which greenstone breccias are usually associated. The water from the dioritic rocks always contains much bitter salts, while from the pool in the granites and breccias it is always sweet. The sedimentary rocks of the interior limestone ranges are regarded as probably, in the main, Cretaceous. In the map, which is based on those of Gottberg, Lepsius, and Kiepert, an effort has been made to give some idea of the hill-complexity of the region. While the general geography of the district north of lat. 27° N. was established on a definite basis by the work of Schweinfurth himself, his geological material, sections, etc., were placed in the hands of Prof. K. von Zittel, who, though he had not personally visited the Eastern Desert, nevertheless made important additions to the knowledge of this region,[30]-[31] publishing a geological map based on the topography of Schweinfurth. His discussion of the distribution of the Cenomanian strata to the north of the present area is of special importance, Zittel being also the first to suggest that some of the Cretaceous beds cropping out in the Nile Valley, near Jebel Zeit, and near Qosseir, were probably Campanian or Dordonian in age. Von Zittel.

Several important botanical works had already dealt with the Egyptian flora, 1884. Forskal[32], and Delile[33] having described many of the most important genera, Boissier. while the value of Delile's contribution is further enhanced by the beauty of the plates accompanying the description, but in 1884 E. Boissier[34] published an exhaustive catalogue in five volumes, which though too bulky for general use, is essential to specialists.

The year 1885 is chiefly notable for a series of papers on matters of detail, Schweinfurth[35] publishing the results of an interesting antiquarian research, while Rutley[36] dealt with the imperial porphyry of Dokhan, and Barois[37] gave a general account of the petroleum district of Jebel Zeit (see section on Petroleum). The Petroleum industry was at this time arousing much interest, a series of papers following each other in quick succession. Sir John Ardagh[38] ascribed its origin to the destructive distillation of carbonaceous matter existing in a lower stratum, the source of heat being either that natural to the earth, or

[29] "Die Umgegend von Qosseir am Rothen Meere." *Zeitschr. der Gesells. für Erdkunde zu Berlin*, XIV, 1879, pp. 401-436 with map.

[30] "Ueber der geologischen Bau der Lybischen Wüste." *Festrede in den kgl. Bayrischen Akad. Wissenschaften*, 1880.

[31] "Beiträge zur Geologie u. Palaeontologie der Libyschen Wüste", Cassel, 1883, pp. CXLVII.

[32] Flora ægyptiaco-arabica, Hauniæ, 1775.

[33] "Flore d'Egypte," extrait de la *Description de l'Egypte*.

[34] "Flora Orientalis," Geneva, 1867-84.

[35] "Alte Baureste und hieroglyphische Inschriften im Wadi Gasus," *Abhandl. Kön. preuss. Akad. Wissensch.* Berlin, 1885.

[36] *Quart. Journ. Geol. Soc.*, London, XLI., 1885, p. 157.

[37] "Rapport sur les Recherches de Petrole de la Mer Rouge".

[38] *Proceedings Roy. Geogr. Soc.*, London, vol. VIII., No. 8, pp. 502-507.

volcanic, or chemical. In this instance, he conjectures that there were carbonaceous deposits, probably vegetable, possibly animal, in the secondary limestone, and that the irruption of the heated masses of porphyritic matter effected their decomposition, they then being condensed in the superincumbent strata. On this theory, he expects all localities, where the two limestones similar to those of Zeit lie adjacent to igneous rocks, to be probable sites for discovering petroleum. The remainder of the paper deals with the question of cost and the history of the work done up to the date of publication.

Mitchell and Stewart. The reports by Mitchell[39] and Stewart[40] deal with the same subject, the former in addition giving a useful description of the desert between Jebel Zeit and the Red Sea Hills. (For further discussion see section Petroleum.) To the same period belongs the exhaustive memoir on the Imperial Porphyry by Schneider[41], containing a map and panorama by Schweinfurth, Brindley[42] also describing his visit to the Porphyry quarries. The origin of the Nile Valley at this period becomes a subject of geological study, Dawson[43], [44] Mayer-Eymar[45], and (later) Hull[46] suggesting that it had formed an arm of the sea in comparatively recent times. It is clear, however, that these writers had not grasped the importance of faulting, Hull shewing the Arabian desert as part of a simple anticline, without faults. Among other points he regards the Nubian Sandstone as having been probably deposited in a vast inland lake, and lays special stress on the importance of a Pluvial period in Egypt, corresponding to the Glacial advance in Europe. Mayer-Eymar[47] also examined a series of new oysters, and noted the presence of Upper Miocene near Jebel Zeit while A. H. Cooke[48] further considered the distribution of the modern Red Sea fauna.

In 1889, Klunzinger[49] again published an account of the region round Qosseir, while Schweinfurth and Ascherson,[50] gave an exhaustive list of the plants in Egypt, together with an account of their distribution and synonomy, a work indispensable to all studying the botany of this region.

1891. Walther. From 1890 onwards papers dealing with the desert rapidly succeed each other, J. Walther,[51] in 1891, giving the first outlines of studies which had as their object an examination of the complicated processes giving rise to desert denudation. This subject has again been treated by him in much detail recently,[52] and the

[39] "Report on the Geology and Petroleum of Ras Gemsah."

[40] "Report on the Petroleum Districts of Red Sea Coast." Cairo, 1888.

[41] "Ueber der rothen Porphyr der Alten," Dresden, 1887.

[42] *Trans. Roy. Inst. Brit. Architects*, 1888.

[43] "Notes on the Geology of the Nile Valley," *Geol. Magazine*, 1884, p. 288.

[44] "Modern Science in Bible Lands."

[45] "Zur Geologie Aegyptens," *Vierteljahrschr. Zürich. Naturforsch. Gesellschaft*, August, 1886.

[46] "Geological History of Egypt and the Nile Valley," *Trans. Victoria Inst.*, vol. XXIV (1890), p. 306, etc.

[47] "Aliæ ostraæ novæ quatuor," *Vierteljahrschr. Naturf. Ges. Zürich.*, 1890, XXXV, (2), p. 177.

[48] "On the Molluscan Fauna of the Gulf of Suez in its relation to that of other Seas," *Annals Mag. Nat. History*, sec. V, vol. XVIII., (1886), pp. 380-397.

[49] "Die Umgegend von Qoseir am Rothen Meer," *Zeitschr. Ges. F. Erdkunde*, Berlin, XIV, 1889, p. 401, etc.

[50] "Illustration de la Flore d'Egypte," *Mem. de l'Institut Egyptien*, 1889.

[51] "Die Denudation der Wüste," Leipzig, 1891, vol. XVI, Abhandl. mathphys. Classe d. Königl. Sächsischen Gesells. der Wissenschaften, pp. 347-569.

[52] "Das Gesetz in Wüstenbildung in Gegenwart und Vorzeit," Berlin, 1900.

views therein expressed are of the highest importance in considering the present structure of the Egyptian Desert. During 1892 three papers were published having a direct bearing on the region under consideration, the most important of these being by E. A. Floyer.[53] In the main the writer deals with the country south of the Qena-Qosseir road, but briefly refers to the northern portion as follows: "To the north of the east-and-west depression of Kena-Kosseir, the ridge rises from 1400–1800 feet, and the masses along the western portion of it are uniformly metamorphic sandstone. Nor does any igneous rock appear till the porphyry quarries of Mr. Brindley are reached in lat. 27° N., where are three parallel lines of upthrust, etc." Comparison with the present memoir will show how materially the views of the writers differ as to the structure of this portion of the desert. Johnson Pasha and H. D. Richmond[54] laid much stress on the intrusion of granite into Nubian Sandstone, a point also urged by Floyer, while Fourtau[55] described a few rock-specimens sent him from the Qena-Qosseir road. 1892. Floyer. Johnson Pasha, etc.

In the following year Dr. Blanckenhorn[56] dealt at some length with the fractures which had produced the Gulf of Suez, the Red Sea, the Aqaba rift, and the Syrian depressions. He considered the Gulf of Suez to have come into existence as a result of trough-faulting, the Red Sea also originating in a similar manner during the Middle Pliocene. The Aqaba rift is here regarded as being younger than the Red Sea itself, while the reason of the advance of the Mediterranean up the Nile Valley as far as Cairo, and the association of a few Indian Ocean shells with those of the northern sea is also discussed. The three typical fault-lines of the desert region between the Red Sea Hills and the Gulf of Suez are also shown in the sketch-map illustrating the relationships of the faults and depressions. 1893. Blanckenhorn.

Capt. H. G. Lyons, R.E.,[57] though treating mainly of the desert to the west of the Nile, nevertheless refers to problems directly bearing on questions discussed in this memoir. He considers the Nubian Sandstone as an estuarine deposit which was gradually invaded by the Upper Cretaceous sea as subsidence continued. This view seems justified by the presence of oolitic iron ore and plant-remains of lacustrine aspect near Wadi Halfa, while on the other hand the finding of marine remains by Barron and Fraas in the upper beds prove the invasion of the sea. Another question bearing on the writers' results is the discussion of the anticlinal folds and erosion of the Nile Valley. It is concluded in the paper that the east-and-west folding took place at a time when the Nile, as it is at present, had not begun to exist, probably in very late Eocene or early Miocene times; while the later north-and-south fold, culminating in the Nile Valley fault at Cairo, finally determined the line of drainage at a later period. A greater rainfall than that existing at present is also regarded as probable. 1894. Lyons.

The establishment of the Geological Survey of Egypt in 1896 led to renewed activity in this region of the desert, while Prof. E. Fraas also traversed the Qena-Qosseir road. The first result of the various expeditions began to appear in 1896. Geological Survey.

[53] "Geology of Northern Etbai," *Quart. Journ. Geol. Soc.* London, vol. XLVIII, 1892, pp. 576–581.

[54] "On Geology of Nile Valley," *Quart. Journ. Geol. Soc.*, London, vol. XLVIII, 1892, pp. 483, etc.

[55] "Les minéraux de la région Keneh-Kosseir," *Bull. Inst. Egyptien*, Mai, 1892.

[56] "Die Strukturlinien Syriens und des Roten Meeres," *Von Richthofen Festschrift*, 1893.

[57] "On the Stratigraphy and Physiography of the Libyan Desert of Egypt," *Quart. Journ. Geol. Soc.*, London, Nov. 1894, vol. L, pp. 531–547.

Bullen Newton. 1898, Bullen Newton writing a series of papers on the palæontological finds made by the Survey parties[58-62]. In No. 58 two new species are described, *Ostrea Lyonsi*, which was first obtained in the Cretaceous beds near Bir Mellaha, and *Trigonoarca multidentata*, a fossil occurring in great abundance at Duwi and near Qift. *Ostrea Villei* and several other forms were also identified, their probable age being suggested as Turonian. In No. 59 the most important description is that of *Pecten Mayer-Eymari*, which is referred to the Lower Libyan division of the Eocene series, No. 60 contains an account of the large Miocene oysters found west of Jebel Zeit, including *O. gingensis* Schlotheim, *O. Virleti*, Deshayes, both of which are referred to the Tortonian, or Upper Miocene. Finally in No. 62, 157 shells are named from the collection made in the Red Sea raised coral reefs and beaches, the deposits containing them being mainly classed as Pleistocene.

Chapman. In the second half of a paper on the Patellina Limestone of Egypt, F. Chapman[63] describes five foraminifera from the valley limestones near Erment, which form the palæontological base of the view expressed in Section II., of this memoir, that these beds were marine in origin, and showed the extension of the sea up the Nile Valley as far as Esna.

Blanckenhorn. Dr. Blanckenhorn, who as palæontologist to the Survey from 1897 to 1899 had enjoyed exceptional opportunities of studying the field reports and collections as they were sent in, and also of examining the older finds of Sickenberger, Willcocks, and Mitchell, has since his return to Germany been enabled to further examine the rich material gathered by Schweinfurth, Zittel, and Fraas. The results of his studies have been published in a series of papers.[64-67] In the first of these the fossil-bearing Cretaceous limestones of the desert are regarded as Campanian, and the Nubian Sandstone as Santonian, but his further subdivision into an Oyster or Bivalve Facies on the one hand, and a Cephalopod or Fish-Facies on the other, is not tenable. For further criticism of this memoir see pp. 182–183 of report. No. 65, being based to a larger extent on personal experience, is an important contribution to our knowledge of the Egyptian Eocene, while in No. 66, the whole of the Miocene beds in Egypt are regarded as Lower Miocene.

No. 67 refers the Miocene beds near the Gulf of Suez to the Middle Miocene or Helvetian, the Lower Miocene being not definitely recognized. The second half is devoted to the description of a series of Miocene fossils, the Pectens especially receiving attention.

[58] "On some Cretaceous Shells from Egypt," *Geol. Mag.*, N. S., Dec. IV, vol. V, pp. 394–403. September, 1898.

[59] "Notes on Lower Tertiary Shells from Egypt," *Geol. Mag.*, N. S., Dec. IV, vol. V, pp. 531–541, December, 1898.

[60] "Marine Miocene Shells from Egypt," *Geol. Mag.*, N. S., Dec. IV. vol. VI, pp. 199–215, May, 1899.

[61] "Egyptian Newer Tertiary Shells," *Geol. Mag.*, vol. VI, pp. 402–407, September, 1899.

[62] "Pleistocene Shells from Raised Beach Deposits of the Red Sea," *Geol. Mag.*, vol. VII, pp. 500–514, and 544-560, Nov. and Dec., 1900.

[63] "*Geol. Mag.*, N. S., Dec. IV, vol. VII, pp. 3-17, January, 1900.

[64] "Neues zur Geologie und Palæontologie Ægyptens. "*Zeitschr. d. Deutsch. geol. Gesellschaft.* Jahrg. 1900, pp. 21–47.

[65] "Ibid. II. Das Palæogen." Jahrg. 1900, pp. 403–479.

[66] "Das Neogen in Ægypten und seine Pectinidenfauna." *Centralblatt für Mineralogie.* 1900, pp. 209–216.

[67] "Neues zur Geologie und Palæontologie Ægyptens. III. Das Miocän." *Zeitschr. d. Deutsch. geol. Gesellschaft.* Jahrg. 1901, Bd. 53, Hft. 1, pp. 52–132.

Permission was also granted to the members of the Geological Survey to publish some of the principal scientific results in the Proceedings of the International Geological Congress, Paris, 1900. Though the main volume (in French) is not yet completed full translations or abstracts have been printed either privately or in scientific journals. Thus Beadnell[68]-[69] announced that a great unconformity existed between the Eocene and Cretaceous series in the Libyan desert, the same discovery for the Eastern Desert having been made independently by the writers before being aware of Beadnell's conclusions. The latter was described by them in a short abstract,[70] which also contains an account of the main conclusions so arrived at with regard to the geology of this region, while the fuller description will be found in the Congress volume. **Beadnell.** **Barron and Hume.**

Hume[71]-[72] has concluded from the study of the neighbouring district of Sinai, that the rifts of these regions fall into two categories, not only the larger features, but many minor valleys, owing their origin to such fractures. The Suez, or N.W.-S.E. running type, has been shown in the present memoir to be the cause of the longitudinal valley of Wadi Qena. **Hume.**

A series of Survey Reports have already made their appearance, most of which bear in some measure on the results obtained in this volume. The first of these was a report on the Phosphates[73] which Barron first discovered near Qift. In this memoir Barron describes the Phosphatic beds of Qift, Hume beds of similar nature between Qena and Qosseir, Beadnell those discovered by him in Dakhla oasis, while A. Lucas gives a chemical report on the occurrences. Ball[74] in the report on Kharga Oasis gives reasons for believing that the Eocene Cretaceous unconformity is also present in that locality. **Report on Phosphate.** **Ball.**

Beadnell in the Farafra Oasis Report[75] deals with the existence of the Eocene-Cretaceous unconformity in that region, while the Dakhla Oasis Report[76] contains an account of the phosphate deposits already referred to above.

While most of the recent work on the Eastern Desert region is directly connected with the Geological Survey of Egypt, some important memoirs have also appeared which deal independently with this region. In 1899 Dr. Schweinfurth[77] published an interesting archæological paper, while Prof. A. Issel[78] in his work on the origin of the Red Sea emphasizes five propositions. (1) The Arabic depression (practically the Red Sea) was originally a lake. (2) The Nile entered this lake, which occupied the basin of the Red Sea, during the Pliocene period. (3) The present sea was formed quite recently, *i.e.* in Postpliocene times, by the opening of the straits of Bab-el-Mandeb. (4) For a short time there was com-

[68] "On some Recent Geological Discoveries in the Nile Valley and Libyan Desert," *Geol. Mag.* N. S., Dec. IV, vol. VIII, pp. 23–28.

[69] "Recent Geological Discoveries in the Nile Valley and Libyan Desert," an English translation of the Congress paper. Dulau & Co.

[70] "The Geology of the Eastern Desert of Egypt," *Geol. Mag.*, N. S., Dec. IV, vol. VIII, pp. 154–161, April, 1901.

[71] "The Rift Valleys of Eastern Sinai," *Geol. Mag.*, N. S., Dec. IV, vol. VIII, pp. 198–200.

[72] "Geology of Eastern Sinai," *Geol. Mag.*, N. S., Dec. IV, vol. VIII, pp. 200-205.

[73] "On the Phosphate Deposits of Egypt," Cairo, 1900.

[74] "Kharga Oasis: Its Topography and Geology," p. 94.

[75] "Farafra Oasis: Its Topography and Geology," p. 36.

[76] "Dakhla Oasis: Its Topography and Geology," p. 107.

[77] "Bega-Gräber. *Verhandl. der Berliner anthropologischen Gesellschaft*," 1899, p. 552.

[78] "L'origine et la formation de la Mer Rouge," *Bull. Soc. Belge Géologie*, Avril, 1900, pp. 65-84.

munication between the Mediterranean and the Red Sea by the estuary of the Nile, and (5) A series of complicated up and down movements are suggested. In support of the second argument it is pointed out that the central zone of the Isthmus of Suez is nearly covered by Nile sediment, while at Chelouf-el-Terraba are thick beds of *Ætheria Caillaudi*, and the alluvium contains remains of *Hippopotamus* and fish, No. 4 is brought in to explain the mixture of European and Erythræan types noted by Mayer-Eymar in the neighbourhood of Cairo.

Walther's[63] important work in connection with Desert Denudation has been previously mentioned.

An important paper by Prof. E. Fraas contains the results of his researches made when traversing the road between Qena, Luxor, and Qosseir, including in addition to many interesting details, the earliest recognition of the existence of strike-faulting near Qosseir, the writer having visited the locality six months earlier than the Survey expedition. He also obtained a collection of Campanian fossils at El Qurn, and Santonian oysters in the Nubian Sandstone. This paper contains the first geological description of the country between Luxor and Qosseir.

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PLATE I

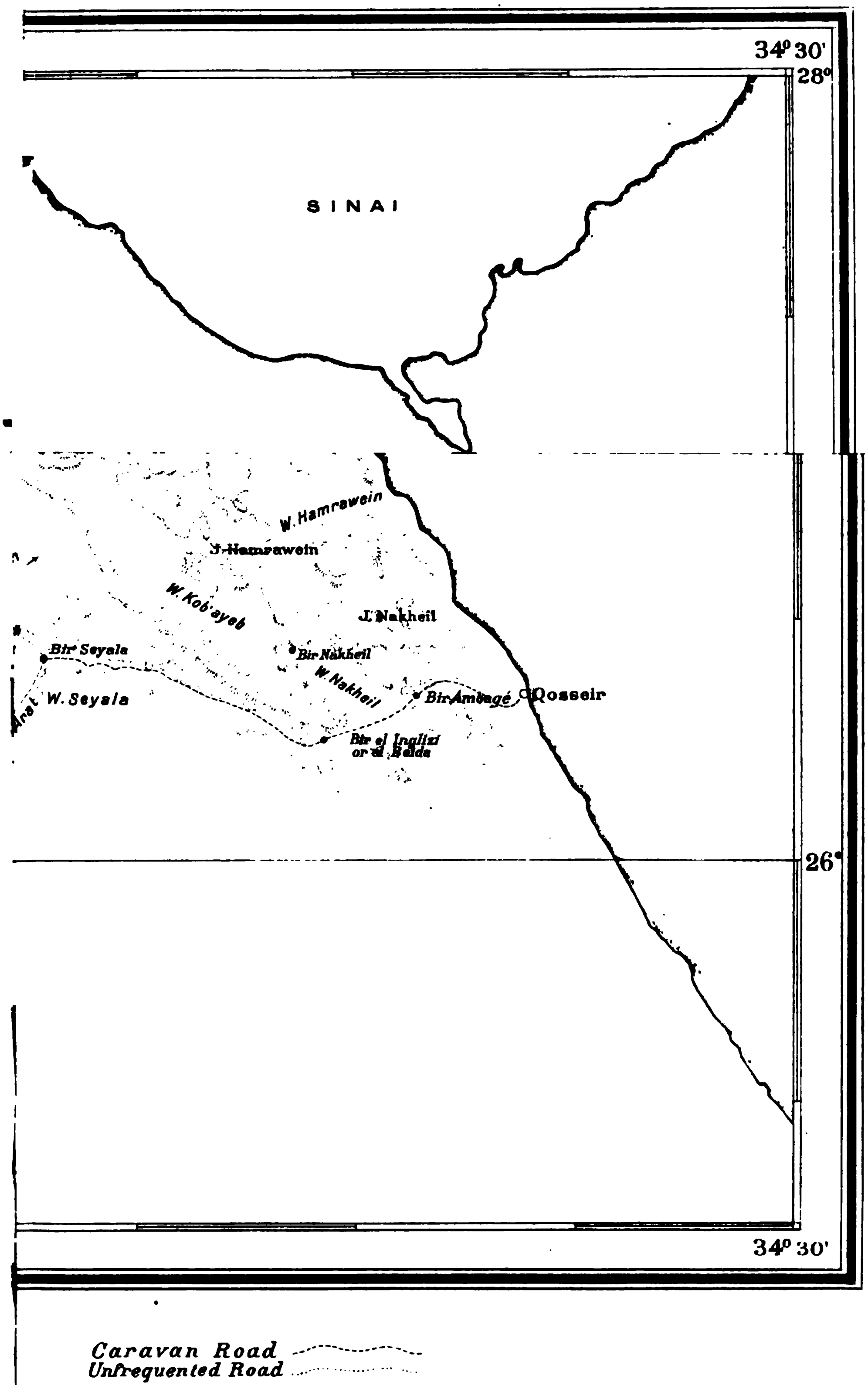
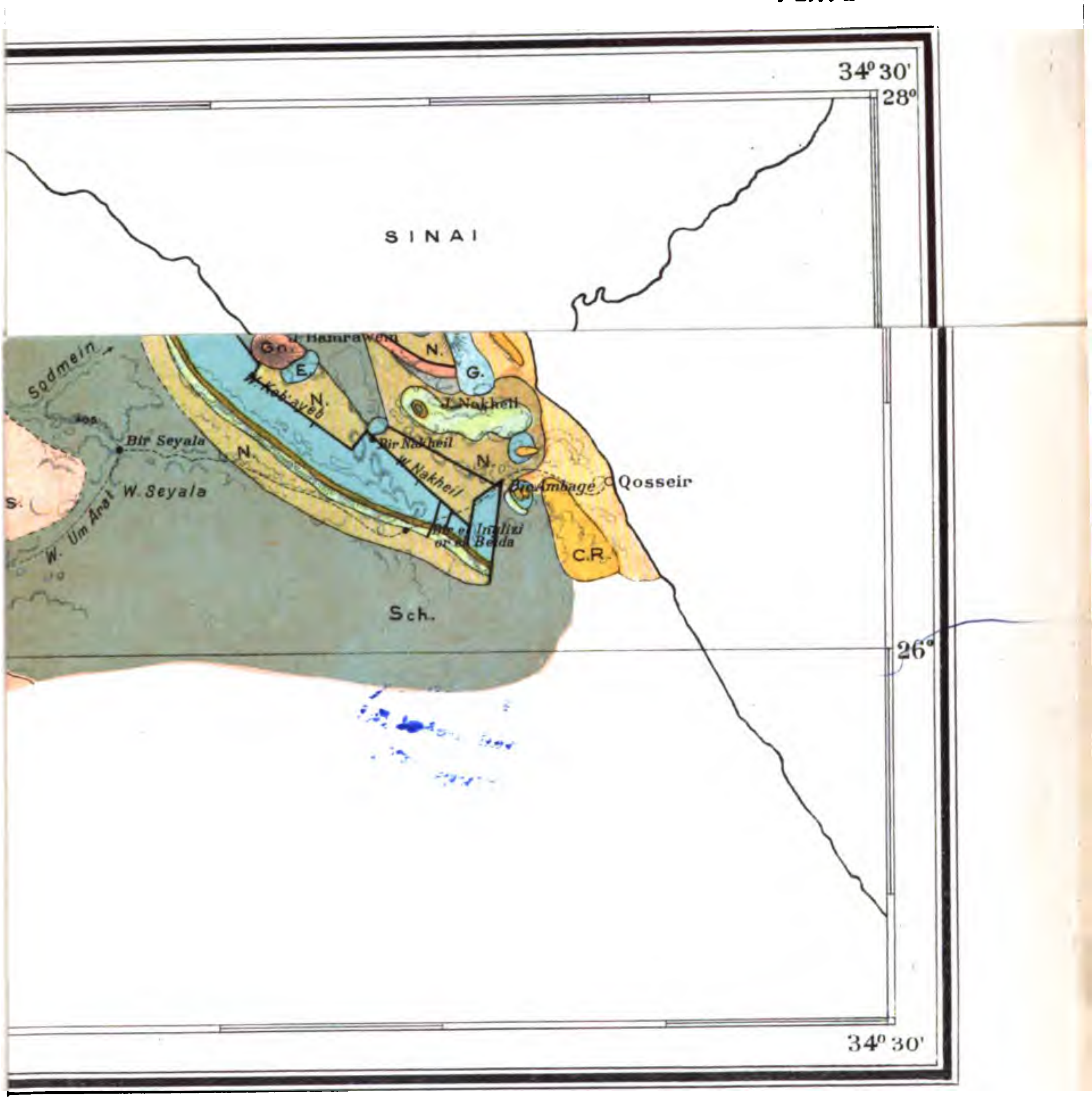

34° 30'
28°
SINAI
W. Hamrawein
J. Hamrawein
W. Kob'ayeb
J. Nakheil
Bir Seyala
Bir Nakheil
W. Nakheil
W. Seyala
Bir Ambagé
Qosseir
Bir el Inglizi
or el Belda
26°
34° 30'
Caravan Road
Unfrequented Road

PLATE II



bmetres

Caravan Road
Unfrequented Road

n. *Red Granite, Diorite & Granitoid Gneiss*

Dokhan Andesites & Porphyry

Schists associated Volcanic rocks.

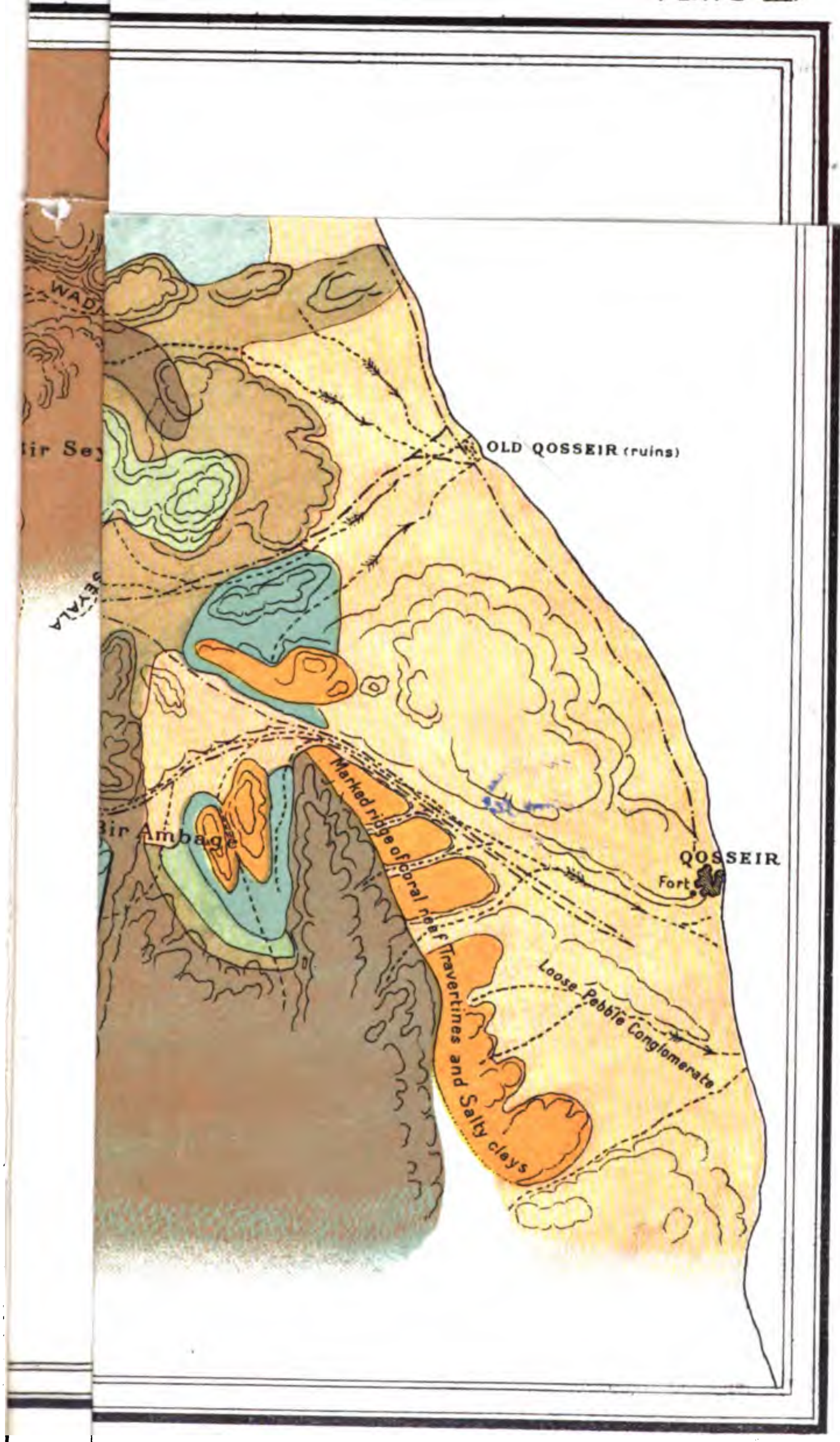
Felsites.

Gs. *Meeteq Gneiss*

R *Relations undetermined*

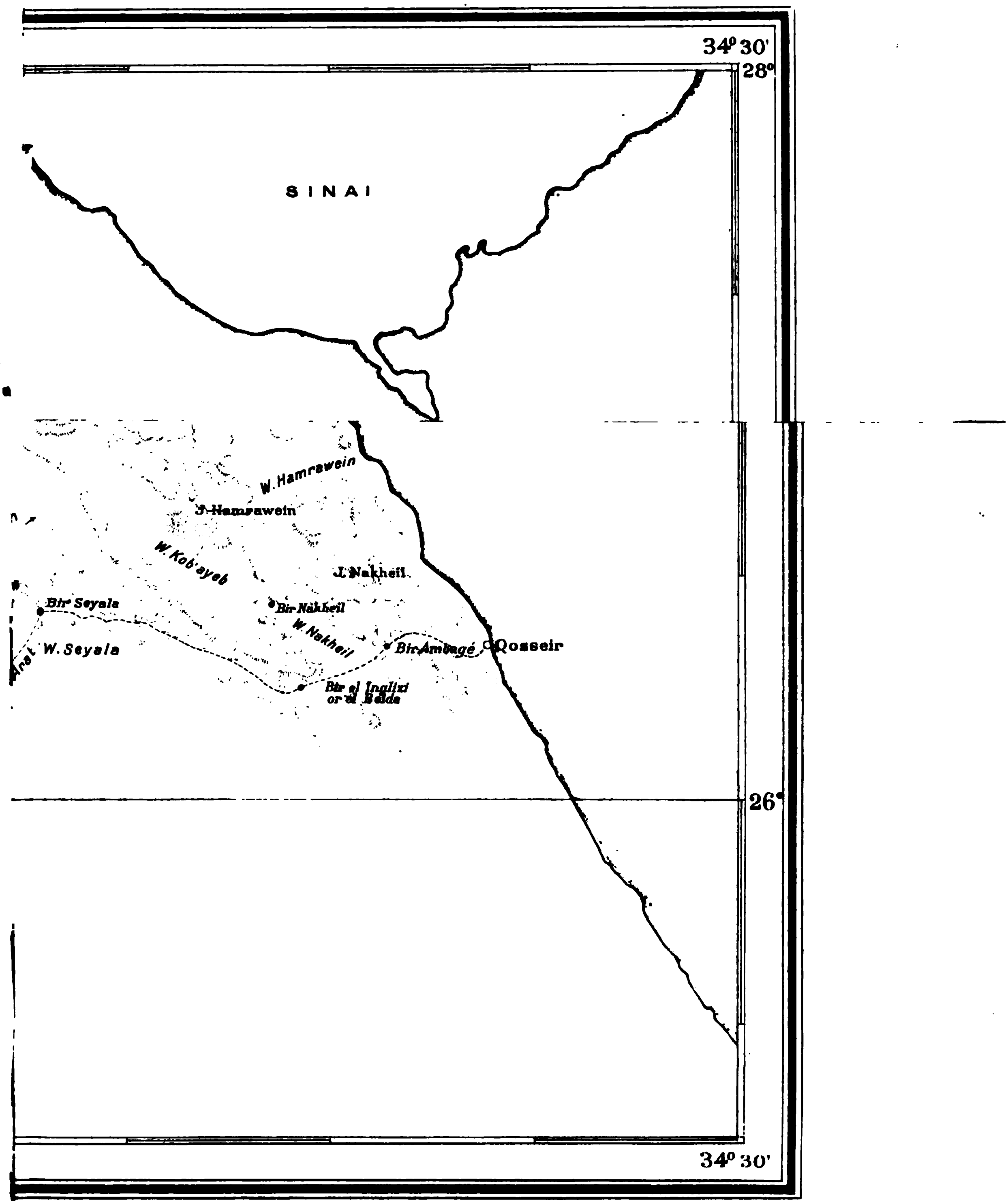
Fault lines.

PLATE III.



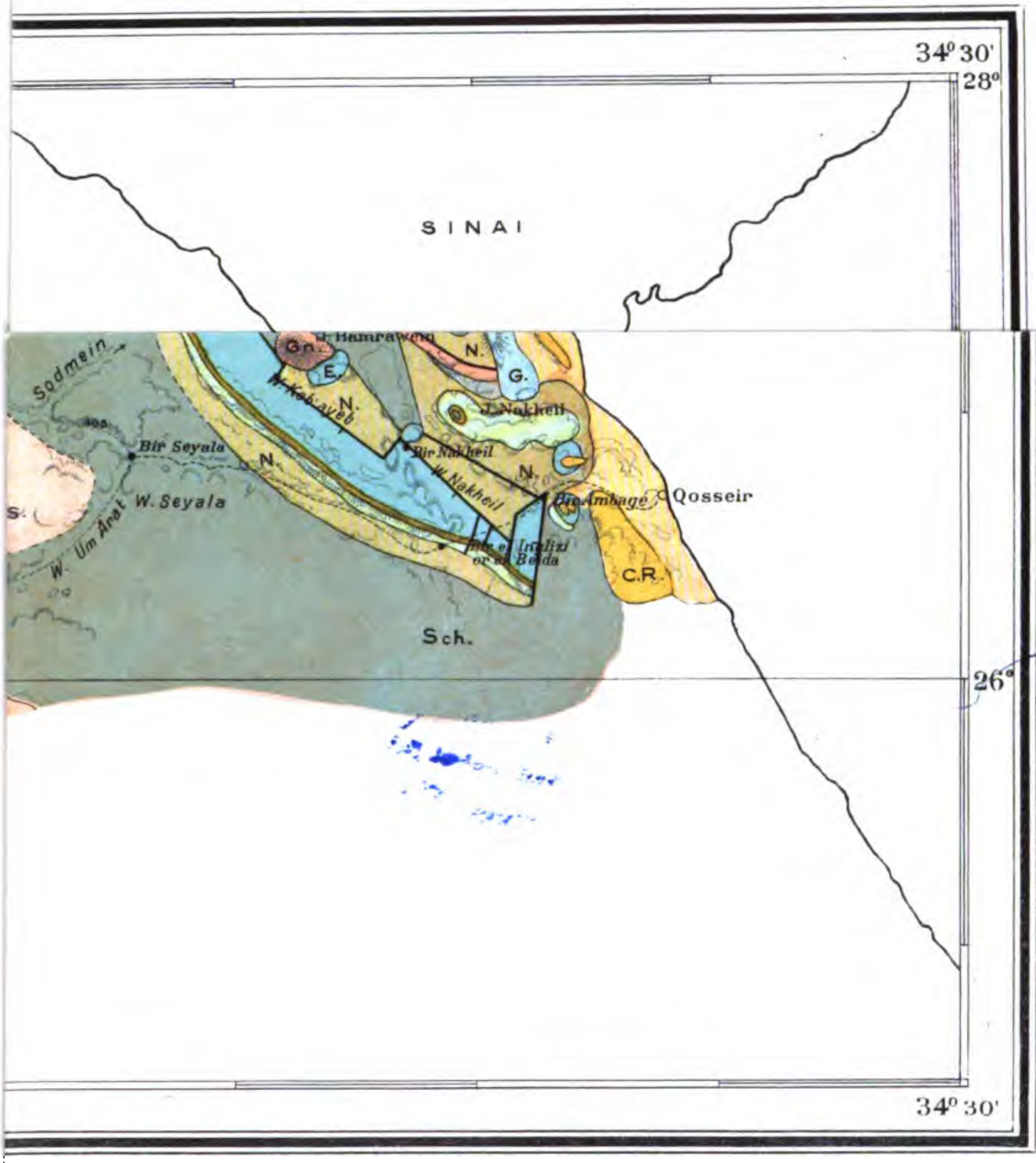
WADI
Bir Sey
SEYALA
OLD QOSSEIR (ruins)
Bir Ambage
Marked ridge of coral reef Travertines and Salty clays
QOSSEIR
Fort
Loose Pebble Conglomerate

PLATE I



Caravan Road
Unfrequented Road

PLATE II



ometres

Caravan Road
Unfrequented Road

n. *Red Granite, Diorite & Granitoid Gneiss*
Dokhan Andesites & Porphyry
Schists associated Volcanic rocks.
Felsites.
Gs. *Meeteq Gneiss*
R *Relations undetermined*
Fault lines.

PLATE III.

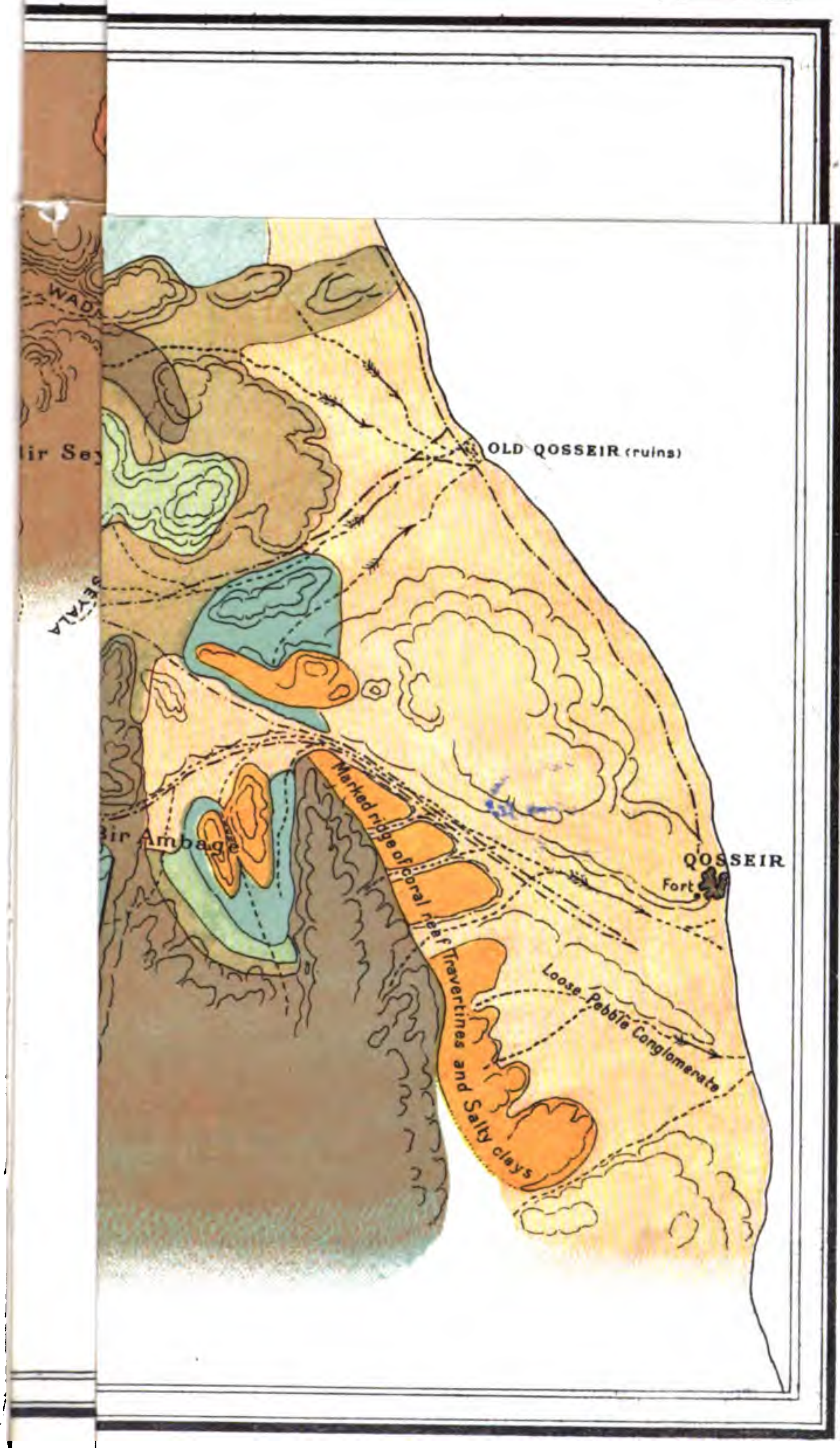

OLD QOSSEIR (ruins)
QOSSEIR
Fort
Bir Ambage
Marked ridge of coral reef
Travertines and Salty clays
Loose Pebble Conglomerate
WAD
ir Sey
SEYALA

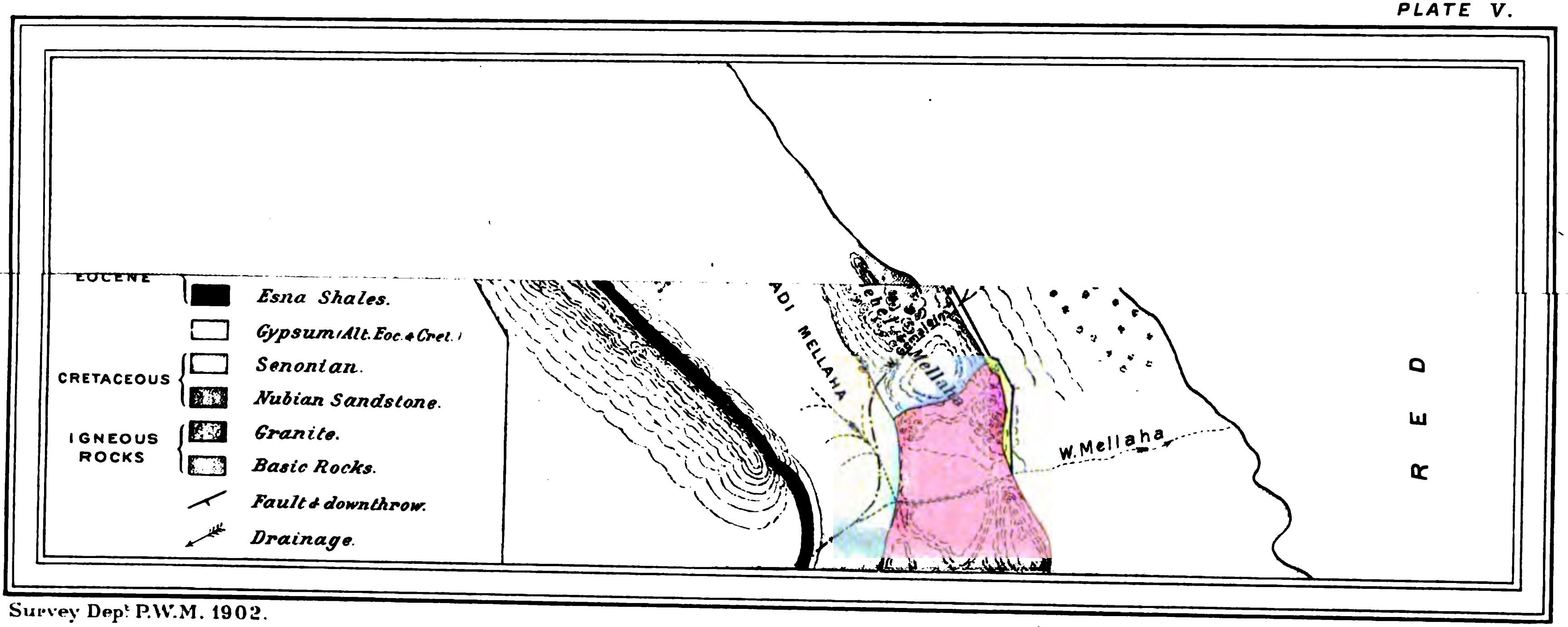
PLATE IV.

DEX TO COLOURS

- *Igneous gravel & beach deposit.*
- *Coral reef and raised beach.*
- *Limestone.*
- *Esna Shales.*
- *Gypsum, formed from Lower Eocene & Senonian limestones.*
- *Limestone.*
- *Nubian Sandstone.*
- *Dolerite.*
- *Granite.*
- *Quartz-Diorite.*
- *Fault.*
- 15° *Dip.*
- *Drainage.*

MAP OF JEBEL ZEIT AND JEMSA DISTRICT.

PLATE V.

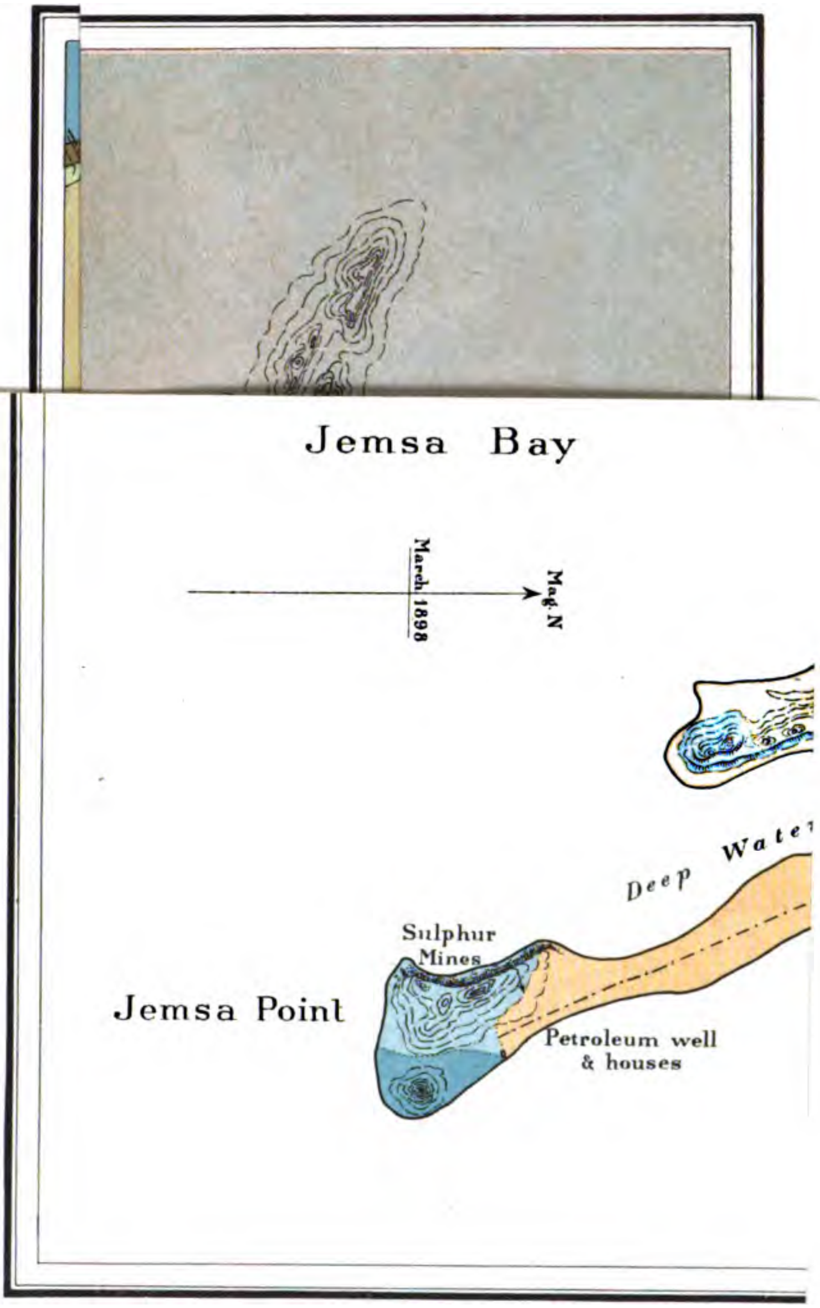


Survey Dept. P.W.M. 1902.

Scale 1:250,000.

Km. 5 0 5 10 Km.

PLATE VI.



Survey Dep^t P.W.M. 1902.

Metres[1]

PANORAMA II.

A HILLS

SKETCH - SECTION SHOWING PRE-MIOCENE FAULTING & POST-MIOCENE MOVEMENT AT WADI DARA.

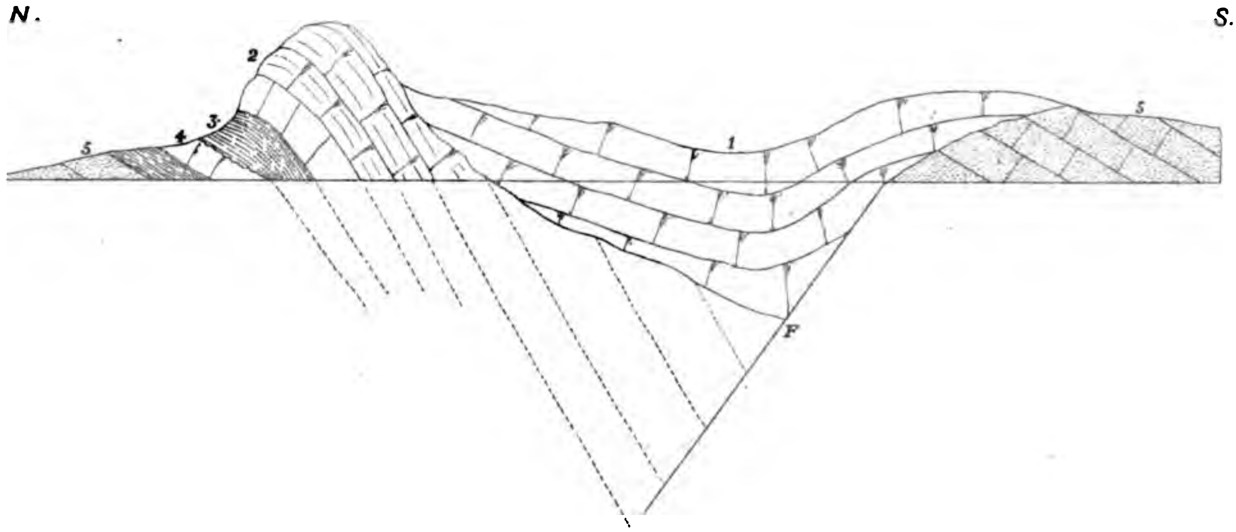
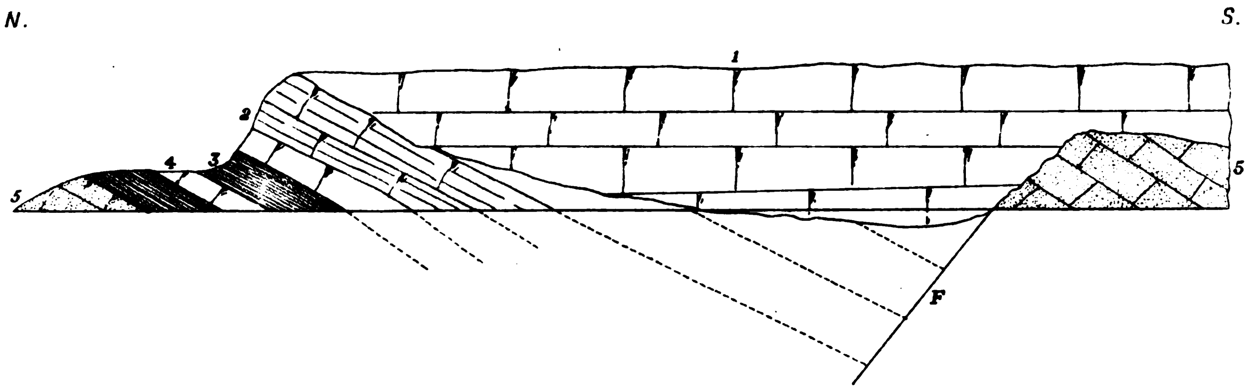


DIAGRAM SHOWING THE POSITION OF THE ROCKS DURING THE DEPOSITION OF THE MIOCENE.



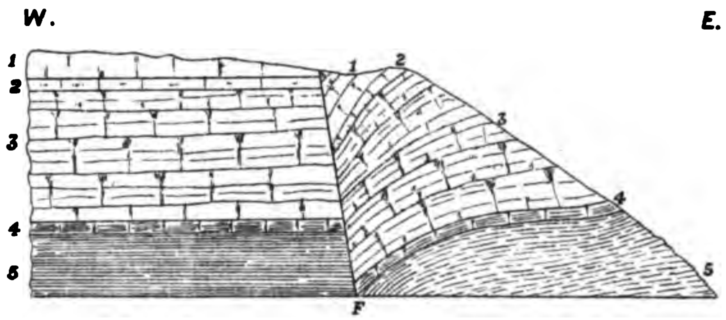
MIOCENE — *1. Limestone.*

LOWER EOCENE — *2. Limestone with flint bands.* / *3. Esna Beds.*

CRETACEOUS — *4. Limestone.* / *5. Nubian Sandstone.*

F. Fault.

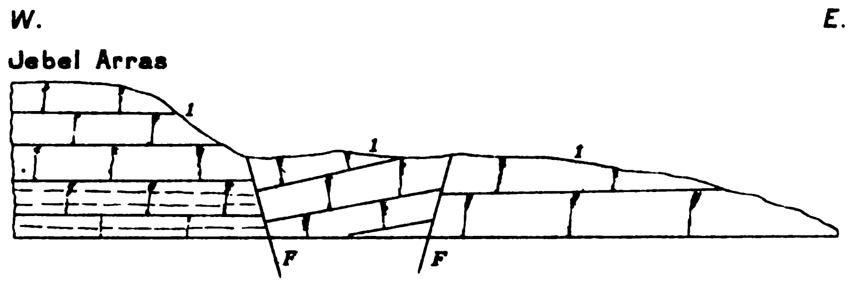
1. SECTION SHOWING FAULTING AT SOUTHERN END OF ABU HAD.



LOWER EOCENE
1. *Nummulitic Limestone.*
2. *Nodular Limestone.*
3. *Limestone with flint bands.*
4. *Pink Limestone.*
5. *Esna Shales.*

F. *Fault.*

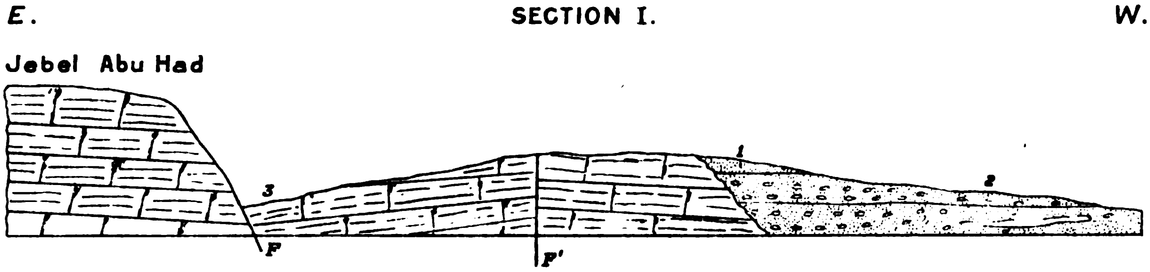
2. SKETCH OF TROUGH-FAULT WEST OF WADI QENA

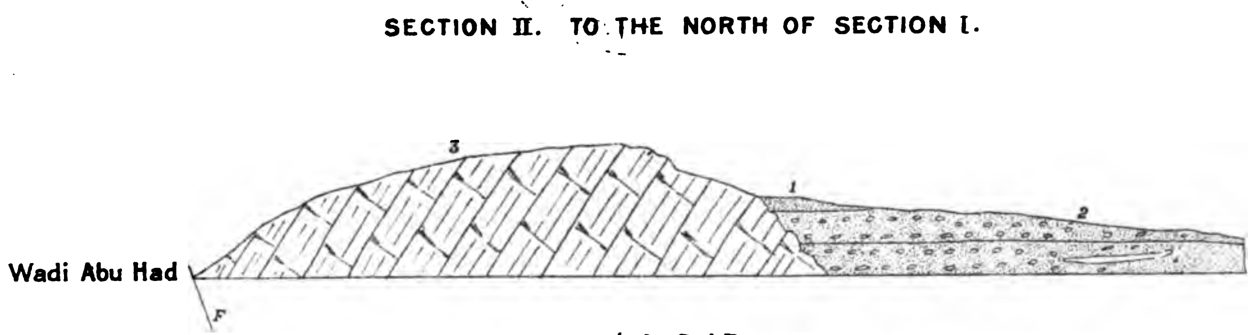


LOWER EOCENE 1. *Limestone with flint bands.*

F. *Fault.*

SKETCH-SECTIONS ACROSS THE NORTH END OF THE WESTERN SPUR OF ABU HAD.





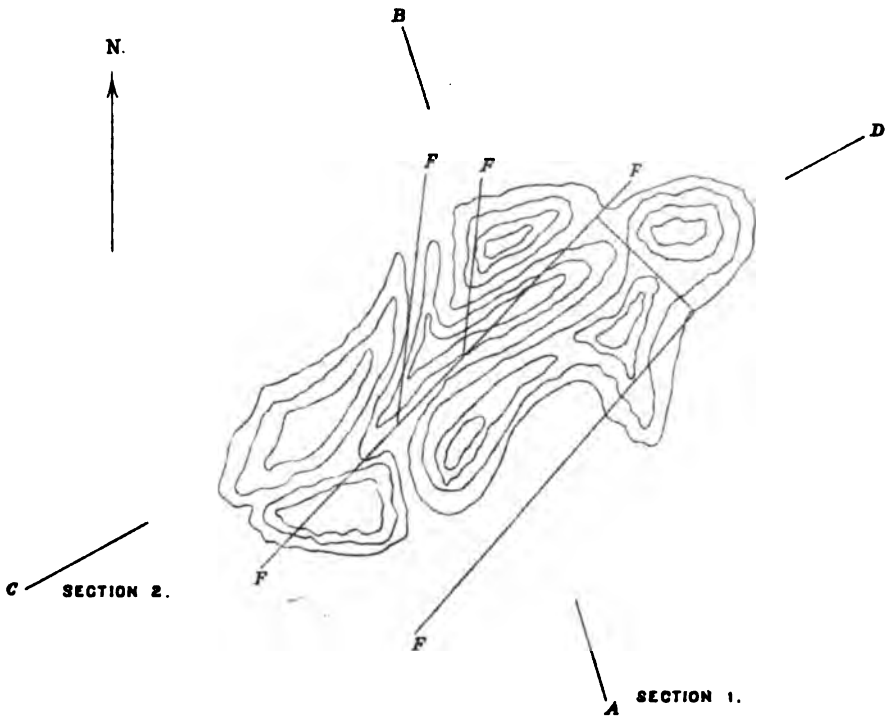
PLIOCENE { 1. *Red Breccia.*
2. *Conglomerate etc.*

LOWER EOCENE 3. *Limestone with flint bands.*

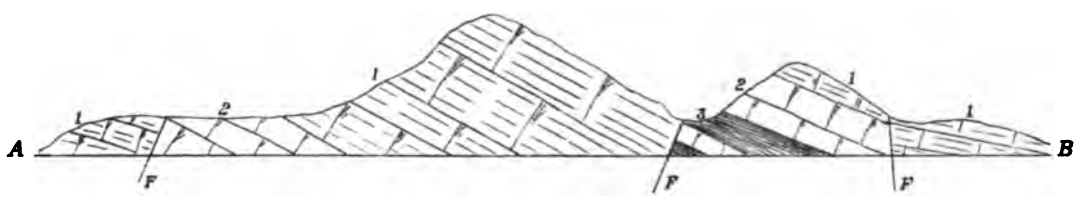
F. } *Faults.*
F'

SECTION VI.

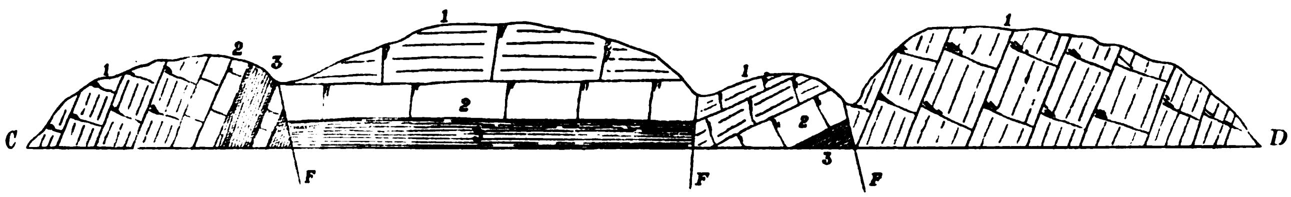
DIAGRAM AND SECTIONS OF A SMALL DOME IN WADI ABU HAD.



SECTION 1. ON AB.



SECTION 2. ON CD.

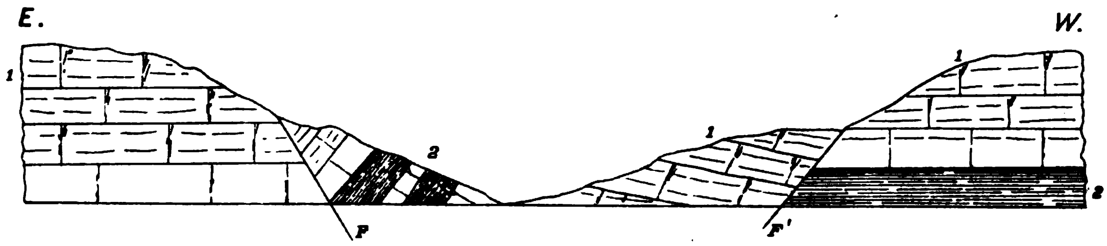


LOWER EOCENE
1. *Flinty Limestone with Flint bands.*
2. *Chalky Limestone.*
3. *Esna Beds.*

F. *Fault.*

SECTION VII.

SKETCH - SECTION IN DUWI RANGE ABOUT 1 KILOMETRE EAST OF QOSSEIR ROAD SHOWING COMBINED DIP AND TROUGH FAULT.

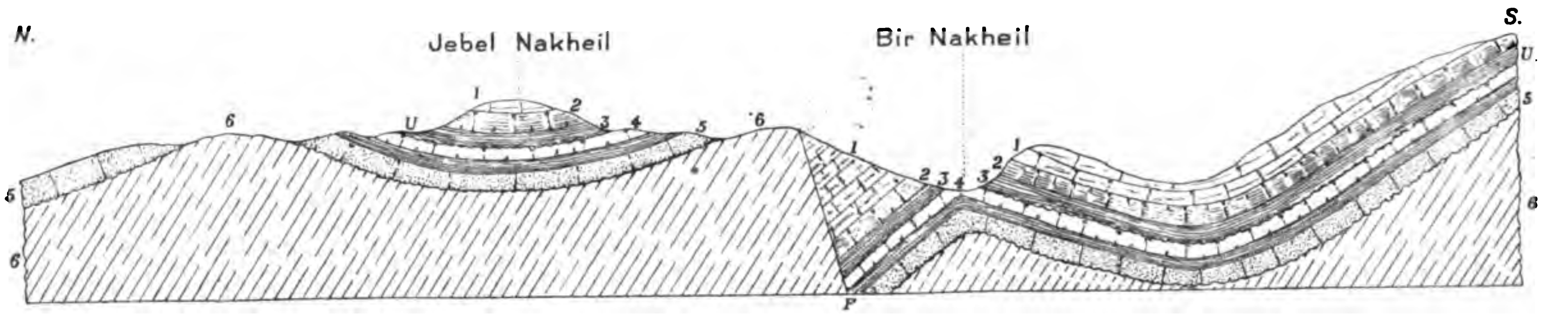


LOWER EOCENE { 1 *Limestone with flint bands.*
2 *Esna Beds.*

F. Dip Fault.

F.' Fault producing the Trough.

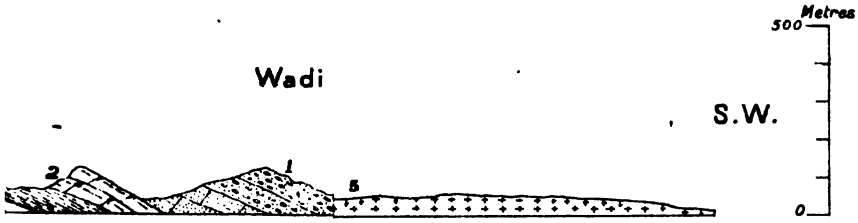
SKETCH-SECTION ACROSS JEBEL DUWI STRIKE-FAULT AND JEBEL NAKHEIL SYNCLINE.

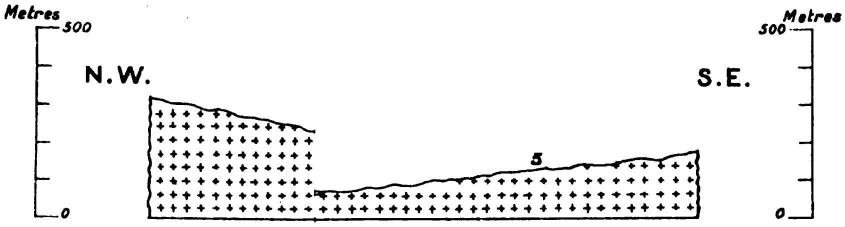


LOWER EOCENE	1. *Flinty Limestone.*
	2. *Pink Limestone.*
	3. *Esna Shales.*
CRETACEOUS	4. *Limestone with Trigonoarca. (Campanian)*
	5. *Nubian Shales & Sandstone.*
IGNEOUS	6. *Sheared Diabase.*
	U. *Unconformity.*
	F. *Fault.*

SECTION IX

ʗTED SYNCLINE ⁄



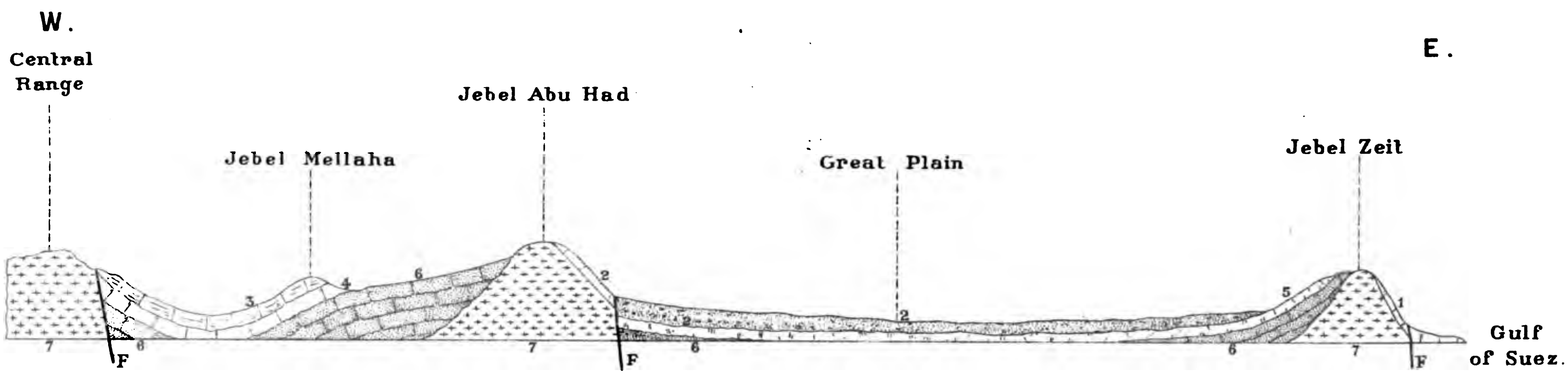


n Line. 124 metres ab

Scale 1: 20.000

0 ½

DIAGRAM - SECTION FROM JEBEL ZEIT TO CENTRAL RANGE.



1 *Pleistocene Coral Reefs & Beach.*
2 *Miocene Reefs.*
3 *Eocene limestone.*
4 *Cretaceous limestone.*
5 *Gypsumised rocks of Nos. 3 & 4.*
6 *Nubian Sandstone.*
7 *Granite, etc.*
F. *Faults.*